PHOSPHORUS RELEASE CAPACITY OF PHOSPHATE ROCK – ANIMAL MANURE COMPOST ON THE GROWTH OF LETTUCE AND SOIL CHEMICAL PROPERTIES.

BY

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DECLARATION

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DEDICATION

I DEDICATE THIS WORK TO GOD ALMIGHTY FOR HOW FAR HE HAS BROUGHT ME

AND

TO MY PARENTS WHO TAUGHT ME TO LOVE AGRICULTURE

ALSO

TO MY WIFE AND CHILDREN WHO TAUGHT ME TO LOVE NATURE

ABSTRACT

The experiments were conducted in 2013 cropping season at the University of Education Winneba, Faculty of Agriculture research field in Mampong Ashanti in the forest transitional zone of Ghana on the Bediase series (FAO/ UNESCO : Chromic Iuvisol) to evaluate the effectiveness of three livestock manures and soil in acidulating Togo rock phosphate to release phosphorus, assess phosphorus release capacity of phosphate rock – animal manure compost on the growth of lettuce and soil chemical properties. The composting materials used were: Togo Rock Phosphate, soil, poultry manure, cattle manure and pig manure. The treatments used were; sole composting material, RP + composting material 1:2, RP + composting material 1:3. A complete randomized design (CRD) with 3 replicates was used. The study established that composting phosphate rock with animal manure significantly released phosphorus. The peak of P release was observed on the 63rd day, with the highest release occurring in RP + PM 1:3. Best performance of P release between the treatment ratios were in the order 1:3 > 1:2 > sole materials. While best performance of P release between the composting materials were in the order poultry manure > pig manure > cattle manure >soil. It was established from the study that phosphocompost application significantly affected the growth and yield of lettuce and N, P and K uptake. Treatment RP + PM 1:3 gave significantly ($p < 0.05$) higher values throughout the growing period than the other amendments and the control in plant height, leaf length, leaf width, leaf area, plant weight and N.P and K uptake. However, all the amended soils were significantly ($p < 0.05$) better in influencing lettuce growth than the control. The application of the phosphocompost increased the soil organic matter content, available P, K, CEC, total N, soil pH, organic carbon, exchangeable bases (Ca, Mg, K, Na), percentage base saturation and decreased exchangeable acidity. It is concluded that composting rock phosphate with animal manure

improved the P releasing ability of rock phosphate as well as leaf length and yield of lettuce. The fresh and dry weights of lettuce were also better in amended soil than control

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Phosphorus is essential for a number of physiological functions which include photosynthesis, respiration, energy storage and transfer, cell division and cell enlargement. Adequate phosphorus is needed for the promotion of early root formation and growth. Phosphorus also improves crop quality and is necessary for seed formation (Tisdale *et al*., 1993).

Phosphorus deficiency is a major constraint to sustainable crop production in many tropical soils. Among essential nutrients, phosphorus (P) often limits plant productivity because of its low mobility resulting from its association with cations (Fe^{2+} and Al^{3+}) or organic compounds that create insoluble and inaccessible complexes in soils (Oswaldo *et al*., 2008; Sanchez, 2006; Logan, 1992). A research conducted by Perri (1991) showed that in many sub- Sahara African countries agricultural practices induced exhaustion of the already low phosphorus reserves.

The need for phosphorus fertilization in Ghana has been amply demonstrated by yield responses of different crops in long term on station fertilizer experiments (Djokoto and Stephens, 1961; Ofori, 1973; Kwakye, 1995). The high cost of water soluble phosphorus fertilizers has affected their usage leading to low crop yield for local and poorly resourced farmers in developing countries. There is wrong timing of release of subsidized fertilizers by government and this has contributed to the low fertilizer use and thus low phosphorus levels in soils in Ghana (Abekoe *et al*. (1999).

The high cost of triple super phosphate in developing countries has necessitated the search for alternative phosphorus sources for small scale or low input farming systems. Developing countries such as Ghana lack the capacity to manufacture phosphorus fertilizers and its importation makes it relatively expensive for the local peasant farmer.

As the cost of industrial P fertilizer rises in developing countries, it has become necessary to look for alternate sources of P for small scale farming operators. Developing nations lack industrial infrastructure and the capacity to manufacture P fertilizer and so must import this commodity. The overhead cost of production is transferred to the local farmers.

P rock, a naturally occurring mineral source of P could serve as an alternative source of P. The rock phosphate may be enriched by composting it with organic materials to enhance the release of phosphorus. Phosphocompost is the term for the end product. It has been shown to be an effective way of incorporating RP with various organic sources.

Abekoe and Agyin –Birikoran (1999) suggested that mixing an unreactive Togo rock phosphate with poultry manure in a ratio of 60 mg P from the TRP: 60 mg P from poultry manure is more effective in increasing dry matter yield and P uptake of maize than using 50 % partially acidulated Togo Rock Phosphate.

Solid waste materials (agriculture and industrial) have been studied in recent time as possible ingredients for composting. Composts are mixed and left to decompose over periods ranging from one to six months to allow sufficient time for organic acids to decompose so the compost will not be toxic to seeds or roots when applied.

Research into alternative and cheaper phosphorus source at the local level is therefore needed to support crop production in developing countries particularly in the sub –

Sahara Africa including Ghana. Phosphate rock, which is a cheaper source of phosphorus than water soluble phosphorus sources, appears to be a reliable and promising phosphorus source to be adopted for application to acid soils with inherently low phosphorus levels (Juo & Kang, 1978).

Rock phosphate (RP) is basically tri-calcium phosphate with non-available P to plant and it is the main raw material for preparing chemical phosphatic fertilizers by treating mostly with sulphuric acid (Das, 2005). In this reaction, two calcium ions are removed by acid and monocalcium phosphate (single super phosphate) is produced (Fertilizer Manual, 1979). Composting RP with organic materials therefore, seems to be a viable option, because various organic acids are produced during the process of decomposition, either by microbes or by chemical reactions. Some organic acids produced during the process are gluconic, fumaric, succinic and acetic acids. Oxalic and citric acids are produced in larger concentrations (Rashid *et al.*, 2004). The other acids produced during the process are carbonic acid (H_2CO_3) produced from evolution of carbon dioxide (CO_2) dissolved in water and nitric acid (HNO_3) produced by dissolution of nitrogen (N) in moisture of the compost. The overall reaction due to acidulation in the compost is as follows:

$Ca_3 [(PO_4)_2] CaCO_3 + 6H_2CO_3 \rightarrow Ca (H_2PO4)_2 + 7CaCO_3$ (Das, 2005)

A survey through the Ghanaian market showed that the retail price for Togo Rock Phosphate (TRP) is cheaper by more than 51 % as compared to triple super phosphate (TSP).

In recent times, 50 kg of both TRP and TSP are presently been sold for GH¢ 40 and GH₵ 78 respectively from Pure and Perfect Enterprise, Tema.

However the phosphate rock is only soluble in acidic soils but in near neutral soils the PR must either be acidulated or amended with organic manure to facilitate the release of phosphorus from it. A large number of known RP deposits in the West – African sub region have been documented by McClellan and Northolt (1986). They reported that with the exception of Tahoua (Niger) and Tilemsi (Mali) RPs, most RPs including those of Togo is of low reactivity, and that there are various ways of enhancing phosphorus release from RP. These include;

- Partial acidulation
- Mixture with water soluble P fertilizers
- Phosphocomposting

Since TRP is low in reactivity, it cannot be used successfully for direct application to increase crop yield, hence prior treatment of the phosphate rock is necessary to release phosphorus through acidulation and to increase the availability of phosphorus for plant uptake.

Works by Khan, and Sharif (2012), Abekoe and Agyin – Birikorang (1999) and Owusu-Bennoah and Acquaye (1996) were limited to the use of only poultry manure to enhance phosphorus release from rock phosphate. There is therefore little or no information on the use of other farm yard manures such as cow dung and pig manures to assess the effectiveness of composting them with rock phosphate to enhance the release of phosphorus from the rock.

1.2 Problem Statement

Most organic materials are deficient in macronutrients content therefore; a large quantity of it is required at a high transportation cost to be applied to satisfy the nutritional demands of crops.

When applied as single entities, the rock phosphate and the animal manures delay in releasing phosphorus early enough and in the right quantities to meet crops demand, hence the need for acidulation of RP with animal manures.

Also, most farmers do not have access to poultry manure as much as they do for cattle and pig manures. In addition, there is inadequate literature on the ability of cattle and pig manures to release phosphorus when composted with rock phosphate. Hence the need for the study.

1.3 Main Objective

This study therefore sought to examine the possibility of using phosphate rock- organic matter compost (phosphocompost) as a phosphorus source on phosphorus deficient soil in the transitional ecological zone at Asante Mampong in the Ashanti region of Ghana

1.4 Specific Objectives

a. Evaluate the relative effectiveness of phosphate rock composted with poultry, cattle and pig manures on the release of phosphorus.

b. Assess the effects of phosphate rock- organic matter compost on some chemical and physical properties of soil

c. Assess the influence of phosphate rock- organic matter compost on the growth, dry matter yield and NPK uptake by Lettuce.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Functions of phosphorus in plants

In the plant, phosphorus is essential for a number of physiological functions which include photosynthesis, respiration, energy storage and transfer, cell division and cell enlargement. Adequate phosphorus is needed for the promotion of early root formation and growth. Phosphorus also improves crop quality and is necessary for seed formation, (Tisdale *et al.,* 1993).

2.2 Phosphorus in Soil

Soil phosphorus is classified in two broad groups, organic and inorganic. The relative proportions of phosphorus in these two categories vary widely from soil to soil, but it is uncommon for more than half the phosphorus to be in the organic form (Brady, 1990).

The total phosphorus content of most surface soils is low, averaging only 0.06 %. This compares to an average soil content of 0.14 % nitrogen and 0.83 % potassium. The total phosphorus (P) content of most soils varies in the range between 0.02 % and 0.2 % with an average of 0.06 %. Total P is usually highest in the surface soil and lower in the sub soil horizons as a result of cycling by higher plants, and also accumulation of soil organic matter (Helal, 1992).

Among the factors influencing P availability include

1. Soil reaction
2. Type of clay mineral
3. Organic matter content of soil

4. Soil moisture
5. Soil temperature and
6. Time of reaction

In strongly acids soils (pH < 5.5) soluble Al^{3+} or Fe^{3+} reacts with soluble orthophosphate ion ($H_2PO_4^-$) to form iron hydroxyphosphate ($Fe[OH]\ H_2PO_4^-$) or aluminum hydroxyphosphate ($Al[OH]\ H_2PO_4^-$). This precipitation reaction reduces the availability of P in acid soils. In alkaline soils, Ca^{2+} reacts with the soluble phosphate forming tricalcium phosphate ($Ca_3(PO_4)_2$) and thus reducing P availability. A similar precipitate is also formed when the soluble P combine with free $CaCO_3$. P availability in most soils is at a maximum in the pH range of 5.5 - 6.5. The influence of type of clay mineral on P availability is exemplified in highly weathered soils where oxides of Fe and Al predominate. The less crystalline or the more amorphous the mineral, the greater the amount of P sorbed and the lower the amount of available P in the soil. This means that soils containing more 1: 1 type clay mineral usually have lower levels of available P than those containing more 2: 1 clays. (Tisdale *et al.*, 1993).

Organic matter decomposition is accompanied by the release of organic acids which solubilize insoluble P compounds and increase the level of available P in the soil. Again, the formation of phosphohumic compounds increases P availability in soil. Also, courses of surfaces of oxides of Fe and Al by organic matter blocks the sorption sites of these oxides and contributes to increased availability of P. Phosphorus availability is enhanced under anaerobic conditions when Fe (III) – P compounds are reduced to Fe (II) – P which are soluble and thus increasing the available P in the soil. Soil temperature regulates soil chemical reactions. Increasing soil temperature favours decomposition of soil organic matter with the release of available P. The optimum soil temperature occurs at about 35 °C beyond which microbial activities are reduced leading to decreased P release. The longer the P is in contact with the P sorbing soil constituents, the greater the amount of P sorbed. (Anderson, 1998).

2.3 Organic Phosphorus

Organic phosphorus is found in plant residues, manure and microbial tissues. Soils low in organic matter may contain only 3 % of their total phosphorus in the organic form, but high organic matter soils may contain 50 % or more of their total phosphorus content in the organic form. Organic phosphorus tends to increase and decrease with organic matter content and hence relatively low in sub soils and high in surface soils. Most organic P compounds are esters of orthophosphoric acid (H_3PO_4) and have been identified primarily as inositol phosphates, phospholipids and nucleic acids (Anderson, 1967). The inositols phosphates are most abundant in soils accounting for 10 – 50 % of the soil organic phosphorus. Nucleic acids and phospholipids constitute 1 – 5 % and 0.2 – 2.5 % respectively of the total organic soil phosphorus (Brady, 1990).

The amount of organic phosphorus in the soil varies from place to place depending on the soil type and climatic factors (Islam and Ahmed, 1973). The inositol phosphates are not readily available to plant (Anderson, 1967). The phospholipids and nucleic acids are more labile and the nucleic acids are susceptible to decomposition to the extent that unless they are protected in some way by stabilizing factors, their accumulation in soil in large quantities is most unlikely (Adams *et al.,* 1994)

2.4 Inorganic Phosphorus

Phosphorus from inorganic sources tend to dominate agricultural soils, typical at 50 – 75 % of total P (Sharpley and Reikolainen, 1997). They are found adsorbed to mineral fractions dominated by either aluminium (Al) or iron (Fe) in acidic soils, or calcium (Ca) in calcareous and alkaline soils.

Chang and Jackson (1957) postulated three divisions of soil inorganic phosphates. These are discrete phosphates precipitated on surfaces of colloidal particles and including chemisorbed phosphate which are the most readily available forms of soil inorganic phosphorus, discrete phosphate particles which are slightly available and occluded phosphates which are but little available. Inorganic forms of P present in a soil depend on the chemical weathering stage of the soil. The proportion of calcium phosphate decreases with weathering while that of iron increases. Calcium phosphates are more soluble than aluminum phosphates, which in turn are more soluble than iron phosphates. In highly weathered soils, most of the inorganic phosphorus is in the occluded or reductant-soluble form because of the formation of iron and aluminium oxide coatings (Sanchez, 1976).

2.5 Phosphorus Status of Ghanaian Soils

Phosphorus has been established to be the most limiting nutrient in Ghanaian soils (Abekoe *et al.,* 1999). The total phosphorus content of soils in the country is low with values ranging from 104 to 252 $mgkg^{-1}$ (Acquaye, 1996) as compared to higher values quoted by Sanchez (1976) ranging between 1000 to 3000 mg/kg for other tropical soils. He however reported much lower values ranging between 20 to 90 $mgkg^{-1}$ for many Vertisols from India.

Junner and James (1947) found the average content of about 15 granitic and 10 basic rocks of Ghana to be 700 and 750 $mgkg^{-1}$ respectively while world average values range between 830 mg kg^{-1} for granitic and 1230 $mgkg^{-1}$ for basic rock. They attributed the low phosphorus in Ghanaian soils to the low content of the mineral apatite in the parent rocks and also to the great age and intense weathering to which the rocks have been subjected (Goldschmidt, 1954).

Acquaye and Oteng (1972) made an observation of a considerable variation in the total phosphorus content of 48 representative soils in Ghana. The range was 2.5 – 53.0 mg P/100g with a mean of 18.7 mg P/100g soil. Acquaye (1996) found that 46 – 70 % of the phosphorus in different soils in Ghana was in the organic form. This fraction is an important source of phosphorus supply to plants only after mineralization. In general savanna soils contain less organic phosphorus than do soils from the forest zone due to the lower organic matter of the former.

The C: P ratio in Ghanaian soils are of the order 200:1, these wide C:P ratios are indicative of phosphorus deficiency in the Ghanaian soils. Available phosphorus content of the soils is generally low ranging from 3.7 – 11.7 mg kg^{-1} this indicates the widespread nature of deficiency of the nutrient in both forest and savanna soils (Acquaye, 1996).

Available P values between 0.1 to 31.5 mg kg^{-1} were obtained by Halm and Bampoe-Addo (1972) when working on 10 representative soil series in Ghana. The low available phosphorus content of Ghanaian soils may be attributed partly to the high phosphorus retention capacity of the soils (Ahenkorah, 1997) and partly to the large proportion of phosphorus which exist in the organic form (Acquaye, 1996).

Factors influencing the phosphorus status of Ghanaian soils (Acquaye and Oteng 1992) are:

- The type of vegetation; The total and inorganic P contents follow the order: forest > forest savanna integrates > Savanna.
- Parent material.
- Organic carbon content.
- pH of the soil.
- Clay content of the soil.

2.6 Percentage Recovery of Applied Phosphorus

Percentage recovery of applied nutrient is often determined by the difference method as the ratio between the differences in yield of nutrient removed on fertilized and control plots and the amount of the fertilizer applied.

It is more correct to determine percentage recovery of a nutrient from a fertilizer against the background of other nutrients incorporated with the fertilizer as opposed to comparison with an experiment without fertilizer application (absolute control) (Fardeau, 1996).

Percentage utilization of P from a P fertilizer is never higher than 15 – 20 % (Fardeau, 1990).

The P in plants derived from fertilizer (% P difference) is always lower than 25 %. Seventy five percent or more of the P taken up by plants is derived from the bioavailable soil P (Fardeau, 1996). Warren (1994), in a pot experiment with six tropical soils, found that the proportion of P recovered by grass ranged from 12 – 51 %. The percentage recovery of applied P depends on soil properties, climatic conditions, and biological characteristics of growing plants, fertilizer rates, types and method of application.

2.7 Phosphate Rock

The phosphate mineral, flour-apatite [$(3Ca_3 (PO_4)_2. (CaF_2)$], is very insoluble, but some finely-ground reactive phosphate rocks can be excellent source of phosphorus. The reactive phosphate rock can be equally effective as water soluble P – fertilizer in suitable soils and environment (Khasawneh and Doll, 1978).

The results of direct field application of phosphate rocks have been very varied. Russell (1973), after reviewing several published reports of phosphate rocks, concluded that phosphate rock has been ineffective in circumstances where it was thought that it should be effective, whereas, elsewhere it has proved useful in circumstances where one would have expected it to be ineffective. Khasawneh and Doll (1978), however, contended that such contradictions and inconsistent behaviour of phosphate rock can be satisfactorily resolved in the chemical and mineralogical composition of phosphate rocks and the application of fundamental and accepted principle of soil chemistry.

In some soils, though phosphate rock may be less effective than water-soluble P fertilizers, it may be more economical to use because it is cheaper (Hammond *et al.*, 1986). However, on neutral and alkaline soils phosphate rock is currently not recommended because the soils possess insufficient hydrogen ions to cause extensive dissolution of phosphate rock (Khasawneh & Doll, 1978). Several West African countries sub of the Sahara have deposits of phosphate rock and direct application of the finely ground phosphate rock and additives applied to it seems to be an economic means for phosphorus fertilization (Juo and Kang, 1978).

2.8 Composition and Chemistry of Phosphate Rock

There are two types of phosphate deposits i.e. sedimentary deposits and igneous deposits. The sedimentary deposits occurred due to upliftment of ancient oceans by earth up-heavals. In these deposits bone and teeth of early fish species are found. The igneous type occurred from molten flows as early earth cooled and solidified. Most phosphate deposits are of the sedimentary type. Apatite is the principal mineral in phosphate rocks, but the apatite in each phosphate rock should be regarded as a distinct mineral species (Chien, 1977).

Sedimentary phosphate rocks are composed of microcrystalline carbonate fluorapatite also known as francolites, which occur in association with a variety of minerals and other compounds. A considerable amount of accessory minerals and impurities are removed by beneficiation, but the beneficiated ore retains some of the original impurities. The nature and quantity of accessory minerals that are found in phosphate rocks have direct influence on their suitability for direct application. The commonest of these accessory minerals include silica, layer silicates, alkaline earth carbonates, and Al oxides, hydroxides, chlorides and sulphates.

The texture of sedimentary phosphate rocks includes the consolidated and unconsolidated. The consolidated rocks are cemented by silica, silicates, carbonates and early oxides of Fe and Al. Unconsolidated rocks are concentrated by secondary geologic process, such as leaching & weathering.

The composition of sedimentary apatites according to Bationo *et al.* (1991) can be represented by the following end-member empirical formula:

$Ca_{10}(PO_4)_6F_2 \rightarrow Ca_{10-3-b}\ Na_3Mg_b\ (PO_4)_{6-x}(CO_3)_x\ FO_{0.42}\ x\ F_2$

Fluorapatite   Francolite type

Apatite can differ by a set of partial substitutions (Bationo *et al.*, 1991) as shown below:

CONSTITUENT ION	**SUBSTITUTING IONS**
Ca^{2+}	K^+, Na^+, Sr^{2+}, Mn^{2+}, Mg^{2+}, Cl^{4+}, Fe^{2+}
PO_4^{3-}	CO_3^{2-}, SO_4^{2-}, SiO_4^{2-}, $AlSO_4^{3-}$, VO^{3-}, $Cr_2O_4^{2-}$, AlO_3^{3-}
F^-	OH^-, Cl^-
O^{2-}	F

The composition of sedimentary apatites can be closely approximated by their contents of Ca, Mg, Na, P, F and C. The phosphate rock deposits found in West Africa are all of the sedimentary type.

2.9 Dissolution of Phosphate Rock

Balland and Gilkes (1990) observed that phosphate rock dissolution was considerably enhanced in permanently moist acid soils with low pH and pCa buffering capacities. Thus, soil acidity has been considered the single most important agent responsible for enhanced availability of phosphorus in phosphate rock materials.

Peaslee *et al*. (1962) expressed that soil pH (vis-à-vis soil pCa) is the most important soil factor in phosphate rock dissolution.

Guaye *et al*. (1986) reported that the solubilizing effect of organic matter on phosphate rock is due to the production of certain organic acids during decomposition of organic matter. Organic acids present in the soil solution include humic, fulvic, oxalic, citric, tartaric, fumaric and glycolic acids.

Kwakye (1986) reported an increase in the solubility of phosphate rock mixed with cow dung as the ratio of the two components increased.

Panda (1990) also observed that decomposing low grade phosphate rock with farm yard manure or green manure for rice-based cropping systems was economical for neutral soils.

2.10 Reactivity of Phosphate Rock

Naturally occurring phosphate rocks (PRs) differ widely in their mineralogy and chemistry. The chemical reactivity or solubility of phosphate rocks is a measure of the PRs ability to release P for plant uptake. It has been shown that the solubility of carbonate-substituted phosphate rock is higher than the solubility of pure fluor-apatite with little or no – carbonate-substitution (Chien and Hammond, 1978).

Increasing carbonate substitution in the phosphate rock increases the ease of breakdown of the structure of the apatite thereby releasing P to the soil solution under acidic conditions. The chemical and mineralogical features are therefore key factors in determining the reactivity and subsequent agronomic effectiveness of a given phosphate rock. A variety of procedures exist for estimating the reactivity of phosphate rocks. The methods include chemical extractants, x-ray diffraction, infrared (IR) procedures, specific surface and elemental analysis. Citrate solubility has become a standard test with which other laboratory test results were evaluated. The conventional citrate solubility is defined as follow:

Conventional Citrate solubility = (quantity of P extracted × 100 / Total P in the PR sample).

2.11 Factors Affecting the Dissolution of Apatite Minerals in the Phosphate Rock

2.11.1 Soil factors

The specific soil properties that influence the dissolution of apatite minerals in the phosphate rocks are; pH, CEC, Ca concentration, P concentration, P sorption capacity and organic matter content.

2.11.2 Soil pH

The dissolution of phosphate rock is enhanced in low pH soils. The following is a simplified equation for apatite dissolution.

$Ca_{10}(PO_4)_6F_2 + 12H^+ \rightarrow 10Ca^{2+} + 6H_2PO_4 + 2F$ (Chien, 1977)

The driving or 'pushing force' for the dissolution of apatites is the neutralizing reaction between proton H^+ ion concentrations and the apatite in phosphate rock. At low pH, the francolite-type apatites are quite unstable and release phosphorus to react with Al and Fe in soil matrix and to form Al and Fe compounds. Low soil pH develops along with other soil conditions such as low exchangeable Ca and high exchangeable Al that also affect phosphate rock dissolution.

Indicators of hydrogen ion supply are soil pH and titratable acidity. Soil pH shows the magnitude of hydrogen ion supply at a given time, whereas titratable acidity indicates the supply of hydrogen ions in the longer term. A linear positive relationship has been reported between initial pH and the titratable acidity in Australia soils (Kanabo and Gilkes, 1987). As a simple guideline, the use of PRs, depending on their reactivity, is generally recommended in soils with a pH of 5.5 or less. The dissolutions of PRs diminish with increasing pH to 5.5 but the decline is more rapid above this pH level (Bolan and Hedley, 1990). When considering a large number of soils, titratable acidity may be a better indicator of PR dissolution (Babare *et al*., 1997)

2.11.3 Cation Exchange Capacity and Exchangeable Calcium and Magnesium

A soil's affinity for Ca promotes the dissolution of phosphate rock because it provides a sink for the Ca that is released by the congruous dissolution of apatite. A low affinity for Ca increases the level of solution Ca at the apatite surface; consequently, the level of $H_2PO_4^-$ / HPO_4^{2-} declines according to the solubility product principle. The gradient of $H_2PO_4^-$ / HPO_4^{2-} between the apatite surface and back solution declines also and the process of phosphate rock dissolution is slowed accordingly. Affinity of a soil for Ca is high when the Ca saturation percentage is low, this condition usually occurs when the overall base saturation and pH are low. A measure of the cation exchange sites available for Ca adsorption is the difference between the cation exchange capacity of soils and the exchangeable Ca (Bolan and Hedley, 1990; Robinson and Syers, 1990).

Recent studies suggest that high exchangeable magnesium (Mg) in soils may enhance PR dissolution (Perrott, 2003). Theory would suggest that, as Mg is held by soils more strongly than Ca, the presence of Mg in the soil exchange sites can block adsorption of Ca released on dissolution of PR and thereby facilitate its removal from the soil-fertilizer system. This will have the effect of enhanced PR dissolution.

The cation exchange capacity of soils is also related to soil texture. Sandy soils usually have a low cation exchange capacity and therefore, do not provide an adequate sink for Ca released from PR. This would lead to a reduction in PR dissolution and in agronomic effectiveness. The other two scenarios occur in areas of sufficient rainfall. The first is where the released Ca may be removed from near the PR particles, with a positive effect on PR dissolution and on agronomic effectiveness. The second is where excess rainfall may lead to leaching of P below the rooting zone of crops and reduce the agronomic effectiveness of PRs. However, because of their slow-release nature, PRs are likely to be more beneficial under such circumstances than water-soluble fertilizers (Bollard *et al*., 1995).

2.11.4 Soil Solution P Concentration and P Retention Capacity

The level of soil P, as expressed by the activity of $H_2PO_4^-$ or by the phosphate potential pH_2PO_4 + 1/2 pCa, plays a role in phosphate rock dissolution. The soil matrix should provide a positive gradient in the electro-chemical potential of both Ca^{2+} and $H_2PO_4^-$ to ensure the congruous dissolution of phosphate rock. If the soil is supersaturated with respect to the particular apatite in phosphate rock, the rock will neither dissolve nor significantly participate in supplying phosphorus to plant roots. Moderately fertile soils with a relatively high soil solution concentration of phosphorus can derive little or no benefit from additions of phosphate rock. (Zapata and Roy, 2004)

As an effective phosphorus fertilizer, phosphate rock effectiveness is limited to soils that are severely to moderately deficient in phosphorus, but it has little or no value in soils of medium to high phosphorus status. Soil texture, soil organic matter and placement methods also influence phosphate rock effectiveness (Khasawneh and Doll, 1978).

Soil texture indirectly incorporates effects of soil clay on CEC – pH relationships and on the ability of the soil to provide a sink for phosphorus.

2.11.5 Soil Organic Matter

Another soil property that increases PR dissolution and its availability to plants is soil organic matter (Johnston, 1954b; Chien *et al.,* 1990b). This seems to arise from:

(i) the high cation exchange capacity of organic matter;

(ii) the formation of Ca-organic-matter complexes; and

(iii) organic acids dissolving PR and blocking soil P sorption sites.

The cation exchange capacity of organic matter is greater than that of clay minerals. Depending on their clay content, the cation exchange capacity of mineral soils may range from a few to 60 $cmol_c\ kg^{-1}$, whereas that of organic matter may exceed 200 $cmol_c\ kg^{-1}$ (Helling *et al.,*1964). The high cation exchange capacity of organic matter means increase Ca retention capacity of soils, which leads to enhanced PR dissolution. Humic and fulvic fractions of organic matter form complexes with Ca (Schnitzer and Skinner, 1969), which can also reduce Ca concentration in solution, leading to enhanced PR dissolution.

2.12 Plant Factors

Plant species differ in their P uptake demand and pattern as well as in their ability to absorb soil solution P (Helyar, 1998; Baligar, *et al.* 2001). Moreover, plant species show differences in their ability to access sparingly forms of P that are unavailable to other plants (Hocking *et al.*, 1997; Hinsinger, 1998; Hocking 2001). Among these, some plants can dissolve and take up the products from PR dissolution (Hinsinger and Gilkes, 1997). For example, perennial pastures, tree crops and plantain crops require a steady supply of P over an extended time span. PRs in soil dissolve gradually and supply P at a steady rate; increasing amounts of PRs are therefore being applied as phosphate fertilizers for the above-mentioned crops (Ling *et al.,* 1990; Pushparajah *et al*., 1990; Chew, 1992). The high agronomic effectiveness of PRs realized with these crops reflects partly the acidic nature of the soils and the high root density. High root density facilitates the intensive exploration of a large soil volume for P because of the presence of a large number of fine roots per unit of soil volume.

Legumes are particularly suited for the use of PRs. They are effective in dissolving PR and in absorbing its dissolution products because of their demand for Ca and the acidifying effect of nitrogen (N) fixation in the soil near the root system (rhizosphere) (Ankomah *et al.*, 1995; Kamh *et al.,* 1999). This effect can be utilized to improve the P nutrition of a companion crop (intercropping) or that of the subsequent crop in a rotation (Horst and Waschkies, 1987; Vanlauwe *et al.*, 2000).

Some plant species (e.g. rapeseed, lupines and pigeon pea) have been studied because of their ability to secrete organic acids that result in an enhanced dissolution of PR (Montenegro and Zapata, 2002 ; Jones, 1998; Hoffland, 1992; Adams and Pate, 1992; Ae *et al*. 1990). Recent studies (Chien, 2003) indicate that reactive PRs may have potential applications even in alkaline soils with organic-acid secreting crops such as rapeseed (canola). Crops that possess high Ca uptake capacity are more suited for PR use. In this respect, finger millet is most suited for PR use, followed by pearl millet and maize (Flach *et al*., 1987).

2.13 Organic Manure and Crop Production

The application of organic material into soil improves the physico-chemical properties of the soils and positively affects the performance of crops.

A study compared the efficacy of livestock manure, crop residue and fertilizer amendments to a degraded soil, cropped with spring wheat. The manures and crop materials were incorporated into the soil at 20 t ha^{-1} dry weight equivalent. The overall best amendments were pig manure, poultry manure and *Medicago sativa hay*. Nitrate-N concentration in the 0 to 60 cm soil depth explained 71% of the variation in restoration ability of the amendments while extractable P-concentration in the 0 – 15 cm depth explained 16% of this variation. Yield from degraded plots amended with pig and poultry manure were not significantly different from plots with no top soil removal (Larney and Janzen, 1996).

The effect of different application rates of organic and inorganic fertilizers on soil physical properties and maize production in a severely degraded soil in Nigeria were studied. Poultry manure application significantly improved average maize height and average maize grain yield. The soil organic matter content was highly correlated with yield. ($r = 0.86$) (Obi and Ebo, 1995).

Four organic manures and NPK were assessed under field conditions for their comparative effects on tomato-growth and yield. Fruits yield were best with swine or poultry manure applied at 10 t ha^{-1}. However, very high manure application i.e. 30 t ha^{-1} depressed growth and yield irrespective of the manure source (Oikeh and Asiegbu, 1993).

Though the nutrient contents of organic manures are far below the inorganic fertilizers as observed in Table 2.1, the application of organic manure will also improve the soil physically and biologically which the inorganic fertilizer cannot do.

Table 2.1 Total N, P and K in some Organic Materials (%)

Organic Source	N	P	K
Poultry Manure	1.50 – 3.00	0.50 – 1.50	0.60
Pig, Horse, Cow dung	0.30 – 0.60	0.20	0.50
Green Manure	1.50 – 5.00	0.20 – 0.50	2.00 – 5.00
Compost	0.50 – 2.00	0.20 – 0.50	0.50 – 2.00

Source: Caplan (1992), Nick and Bradley (1994), Hue (1995), Kettering (1992)

Addition of organic material in any form helps to maintain the organic matter and fertility level of the soil, however, the type of organic material added greatly influences considerably the rate of decomposition as well as the consequent chemical changes brought into the soil (Sarmah and Bardoloi, 1994).

2.14 Ways of improving the Agronomic Effectiveness of Phosphate Rock

The following methods have been recognized to improve the effectiveness of phosphate rock:

a. Acidulation and

b. Composting

In this study, composting the phosphate rock with organic matter was adopted. Composting phosphate rock with organic matter is a biological means of enhancing the solubility of the rock.

The biological means of enhancing the agronomic effectiveness of phosphate rock (PRs) applied as phosphate fertilizers are:

- Composting organic wastes with PR (Phosphocomposts)
- Inoculation of seeds or seedlings with phosphorus-solubilizing micro-organisms (fungi, bacteria and actinomycetes) and the inclusion in the cropping system of crop genotypes that exhibit greater root growth and thus increase the extent of soil exploration, exude proton and organic acids that increase the solubility of sparingly soluble phosphates by decreasing pH and/ or chelation, and produce elevated levels of phosphatase enzymes that can break organic phosphorus (P) down to inorganic P. (Zapata and Roy, 2004)

2.15 Composting

Treating PRs with organic materials and composting them is a promising technique for enhancing the solubility and the subsequent availability to plants of phosphorus (P) from PRs. The technology is particularly attractive where

- 'Moderate to high' reactive PRs are available but unsuitable for the production of fully acidulated fertilizers such as single or triple superphosphate
- Organic manures are applied routinely to maintain the organic fraction of soils and supplement their nutrient requirement (as in most tropical countries) where organic farming is practiced, which excludes the use of chemically processed fertilizers. (Zapata and Roy, 2004).

The enhancement of P release from PRs seems to be a function of the acidification of PR by organic acids and more importantly their chelating ability on calcium (Ca), iron (Fe) and aluminium (Al) (Potilman and McColl, 1986). The greater ability of organic acids, compared with mineral acids of comparable strength, to release P from PR and the direct evidence of their chelating ability have been documented (Kpomblekou and Tabatabai, 1994a). Another important factor in the release of P from PR is the participation of the OH groups in the organic acids. For example, it has been shown that citric acid with three carboxyl (COOH) groups and an OH group was able to dissolve more P from PR than cis-aconitic acid with three carboxyl group but without the OH group (Kpomblekou and Tabatabai, 1994).

Fulvic acid is the most reactive of the humic substances in adsorbing significant amounts of Ca^{2+} and releasing H^{+} ions, thereby enhancing PR dissolution. Humic acid may form complexes with P and Ca, and create a sink for further dissolution of PR (Singh and Amberger, 1990). The application of humic substances to soil also makes more P available to plants by competing for, and by forming a protective coating over soil phosphate-sorption sites. An additional benefit that accrues from the application of phosphocompost is the movement of dissolved P to a greater soil depth, which provides a larger soil volume for P uptake by plant. (Singh and Amberger, 1990).

Organic manure is a broad term that comprises: manures prepared from cattle dung, excreta of other animals, crop residues, rural and urban composts, and other animal wastes. The concentration of nutrients in organic materials is variable. Although most of these materials contain significant amounts of nitrogen (N), they contain little P. The effectiveness of the compost in solubilizing PR varies with the kind and composition of waste material and with the rate of decomposition. It is a function of the magnitude of production of organic acids and chelating substances in the compost, which in turn result from the metabolic activities of microorganisms including bacteria, fungi and actinomycetes. Composting PR with poultry manures may not be the preferred option because poultry manure contains large amount of calcium carbonate and other basic compounds that hinder PR dissolution. (Mahimairaja *et al* 1994).

The rate of decomposition of the organic material can be accelerated by microbial inoculation of the compost (e.g. Aspergillus spp.), and by the addition of energy sources (molasses) to the waste before composting (Singh and Amberger, 1991).

An increase in the agronomic effectiveness of PR in phosphocomposts over that of direct applied PR can be expected because of its greater water-soluble and citric-soluble P contents, which would be available to plants. Moreover, the soluble P fractions should stimulate root growth and facilitate greater exploitation of P enriched soil (Chien *et al.*, 1987a; Rajan and Watkinson, 1992; Habib *et al.*, 1999).

Phosphocompost prepared by mixing farm wastes, cattle dung and soil (as a source of bacteria inoculum) has been found to be as good as single superphosphate (SSP) (Banger *et al.*, 1985; Palaniappan and Natarajan, 1993). The sources were applied on an equivalent total P basis to a tropical soil and the crops were: pigeon pea, green gram, clusterbean, wheat and pearl millet. At pH values higher than 7.5, where directly applied PR is not expected to dissolve, phosphocompost was as effective as SSP (Mishra and Bangar, 1986). However, the P sources were applied at a single rate of P in these studies, which reduces the validity of the results.

Phosphocomposting offers the advantage of using otherwise unusable PRs, and the environmental advantage of safe disposal of organic waste. In situations where organic manures are already in use or are a viable alternative to chemical fertilizers phosphocomposting has an advantage (Mugwira *et al.*, 2002). On the other hand, if phosphocompost is to be applied mainly as a source of P, then the benefits need to be weighed against the cost of preparation and application. Further research is needed to determine scientifically the minimum amount of compost required to solubilize PR to a level where the product would be economically as effective as water-soluble phosphate fertilizers. The research programme should include PRs of different reactivities and various combinations of locally available organic wastes.

2.16 Agronomic Effectiveness of Phosphate rock Compost with Organic Manure

Agronomic effectiveness of a fertilizer, though difficult to define exactly and to quantify (Black and Scott, 1959), it may be described as the transfer of phosphorus from the phosphate rock fertilizer towards the soil phosphorus components, namely; the available, slowly available and unavailable phosphorus, which may be utilized by plant. It can be measured by analyzing the variations of the amounts of the three components of soil phosphorus after phosphate rock application. Chien and Menon (1995) reported of four important factors, which influenced agronomic effectiveness of phosphate rock as, phosphate rock sources, soil properties, management practices and crop species. Similarly, Khasawneh and Doll (1978) found that the agronomic effectiveness of phosphate rock is depended on the chemistry, crystalline and mineral composition, soil factors and crop to be grown. In addition, Hedley *et al.* (1990) observed the rhizosphere pH as one of the factors, which influences the agronomic value of phosphate rock.

The reactivity of phosphate rock, which is estimated by many methods including citrate solubility, is believed to greatly influence its effectiveness. It has been observed that citrate-soluble phosphorus of the apatite increased as the degree of carbonate substitute for phosphate in the apatite structure increased. It was the belief of Chien and Black (1976) that the substitution decreased the free energy formation of carbonate apatite. Based on the citrate solubility of phosphate rock, Diamond (1979) classified phosphate rock for direct application as high when it is 7.5 %, medium when 3.2 % to 5.4 %, and low when it is < 2.7 %.

Cooke (1982) noted that citric acid soluble phosphorus is best used when rapid action is not necessary and when the fertilizer (phosphate rock) can be applied well before crop growth starts. Reports from tests carried out on acid tropical soils have confirmed (depending on the inherent reactivity of phosphate rock) the effectiveness of phosphate rock for direct application (Osunde *et al*., 1992).

Kwakye (1986) cited Klechkovskii and Peterburgskii (1967), from their findings that composting with phosphates not only improved the quality of the compost but also increased the effectiveness of the added phosphorus. In their experiments to ascertain the agronomic effectiveness of poultry manure composted with phosphate rock and elemental sulphur, Mahimairaja *et al*. (1995) found that the phosphate-poultry manure compost was 12 % as effective as urea and was equally effective for the second season maize crop. It was also found that poultry manure increased phosphorus in solution through decreased sorption by the soil.

Sesbania rastrata green manure composted with Morocco phosphate rock gave significantly high rice grain yield than did fertilized with Morocco phosphate rock alone (Medhi and De Datta, 1996). Their results indicate that phosphorus uptake by plants is improved with PR-green manure compost. Medhi and De Datta (1996) further observed from the correlation analysis that there was a close relationship between P uptake and Dry matter (DM) yield and Phosphorus uptake and grain yield. Similarly, phosphate rock mixed with soya bean straw in greenhouse test improved the phosphorus uptake response on neutral or alkaline soil (Rostogi *et al*., 1970).

Abekoe and Agyin-Birikorang (1999) on the enhancement of availability of phosphorus from Togo phosphate rock (TPR) using poultry manure, suggested that, mixing an unreactive Togo phosphate rock with poultry manure in a ratio of 60 mg P from the TPR: 60 mg P from poultry manure is more effective in increasing dry matter yield and P uptake of maize shoot than using 50 % partially acidulated Togo phosphate rock.

Furthermore, Owusu-Bennoah *et al.* (2002) in comparison of greenhouse and ^{32}P isotopic laboratory methods for evaluating the agronomic effectiveness of natural and modified phosphate rock in some acid soils of Ghana, realized that the isotopic kinetic method may be considered as an alternative to both greenhouse and field methods in the evaluation of agronomic effectiveness of P fertilizers in tropical acid soils because it offers comparative advantages in assessing the soil P status and its changes, though trained staff and adequate laboratory facilities are needed.

In the study to evaluate the agronomic potential of different sources of phosphate fertilizers in a typical concretionary soil of northern Ghana, Owusu-Bennoah and Acquaye (1996) concluded that, relative to SSP, the P from residues of PAPR 50 and PR are poorly effective in the soils studied for sustainable crop production.

2.17 Residual Effects of Phosphate Rock

The residual effect refers to the favourable or unfavourable response of crops to nutrients applied previously to crops. Although the apparent initial efficiency and recovery of phosphorus from phosphate rock may be too low, normally it has some residual value. The prediction of the availability of residual phosphorus in the soil would enable the full agronomic and economic values of fertilizer phosphorus to be assessed more correctly. Although high initial rates of P fertilizers are required on the Cerrado oxisols of Brazil, the good residual value means that phosphorus fertilization is economic in the long run (Geodert, 1983). The long lasting effect of residual phosphorus depends on the duration and magnitude of fertilizer applied, crop removal and buffering capacity of soil for phosphorus (Tisdale *et al*., 1993). He also attributed the residual effect of phosphate rock as fertilizer to the much slower entry of phosphorus from phosphate rock into the soils labile pool of phosphorus.

Khasawneh and Doll (1978) reported of evidence of the residual effect of phosphate rock on many acid soils. Osunde *et al*. (1992) observed that extra uptake of phosphorus from the applied Gafza phosphate rock was more pronounced with time, which could be attributed to the residual effect of the phosphate rock. Field experiments on tropical and sub-tropical soils indicate that in the year after application, the residual value of fertilizer phosphorus is often around 50% of the fresh phosphorus (Holford and Gleeson, 1976). On both acidic and basic soils, substantial benefits from residual phosphorus can persist for as long as 5 to 10 years. (Halvorson and Black, 1982). On Kenyan soils significant response occurred up to nine crops and five years after application of the phosphate rock (Boswinkle, 1961).

In Latin America, most of the directly applied phosphate rock fertilizers are used for improved pastures, especially in Brazil and Colombia. Steady yield increases over time have been found on Brazilian Oxisols when applying the otherwise unreactive phosphate rock from Araxa (Leon and Hammond, 1986).

Significant residual responses to phosphorus fertilizers have been reported in many locations in tropical Africa even when the rates of fertilizer applied were minimal (Juo and Fox, 1977; Kang and Osiname, 1979). The low phosphorus sorption capacities of soils account for this phenomenon. It is, therefore, wrong to generalize that soils in the tropics give low phosphorus residual values.

Phosphate rock has been shown to persist in some soils for a long time. Therefore, the residual effects of phosphate rocks are of considerable interest. Engelstad *et al*. (1974) evaluating the residual effect of various rates of both TSP and several sources of phosphate rock concluded that the general superiority of TSP over all sources of phosphate rock persisted through the second crop; a relationship between citrate solubility of phosphorus in phosphate rock and first crop response was largely observed for the second and that the residual effects of most phosphate rocks were substantial.

Bationo *et al*. (1986) found the residual effectiveness of phosphate rock basically applied at three times the rate applied on annual basis was superior to that of annually applied phosphate rock and overwhelmingly superior to that of TSP.

Thus, the availability of phosphorus to the plant is controlled by the concentration of phosphorus in the soil solution due to the dissolution of the phosphate rock over a long period. Inorganic and organic sources of fertilizers are normally used by farmers to improve low soil nutrient status. Farmers however find it easier to regulate precisely the amount of the various nutrients added to the soil by using inorganic fertilizers. It is easier, less time consuming and labour tend to be more immediate than for organic manures which takes time to decompose and release nutrient (Muir, 2002).

The use of natural source of nutrient has gained prominence because of the comparative benefit of increased humus content, increased water holding capacity and improved soil aeration and soil structure.

Phosphocompost is an organic material composted with rock phosphate. In addition to achieving all the above benefit it also releases P particularly in P-deficient soils for plant use.

According to Misra*etal* (2002) phosphate rock composted with paddy straw and phosphorus solubilizing organisms released more P during composting and was agronomically effective for rice production.

Comparison of phosphocompost with single and triple superphosphate has shown that certain mixtures of phosphocompost are capable of producing similar or better yields than the inorganic phosphate fertilizers. A composted mixture of phosphate rock and millet straw was better than compost alone for increased millet yields (Bediane *et al.*, 2001).

Manna *et al,* (2001) suggest that composts consisting of cereal and legume straws, phosphate rock and cow manure produced soybean yield nearly equal to yields produced by application of soluble N and P fertilizers.

Manna *et al* (2001) again reported that soil microbial biomass carbon (SMBC) increased in soil amended with phosphocompost than in soils amended with soluble fertilizers. They say greater increases in soil microbial biomass carbon were obtained with varying phosphocompost made from soybean straw, mustard straw, chickpea straw, wheat straw and city garbage compared to soluble fertilizers. A residual effect of P is an important consideration for resource-poor farmers.

This study, analyzing soluble P fractions in soil showed that very little P was released from phosphocompost after a month compared to Single superphosphate (SSP) however, this slow dissolution over several cropping sequences can make application of phosphocompost economically viable

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

The project was sited at the Multi-purpose Nursery of the University of Education, Winneba, Asante Mampong Campus in the Ashanti Region of Ghana during the major season between March-July, 2013.The site lies North of Kumasi within the transitional ecological zone between the Guinea savanna in the North and the rainforest region of the south. Asante Mampong lies between latitude 0.7 and 0.47 N and longitude 01, 024 W of the equator. It is Also on altitude of 475 metres above sea level (Meteorological Services Department, 2010).

3.2 Climate

According to the Meteorological Service Department of Asante Mampong (2010), the area experiences bimodal rainfall regime. The major rainy season begins from mid-March and ends in July, there is a short dry spell in August. The minor season begins in September and ends in mid-November. The mean monthly rainfall in the area is about 91.2 mm with mean temperature of about 25 °C – 30 °C.

3.3 Cropping History of Site

The natural vegetation (forest) had been greatly disturbed by farming activities (for experimental purposes). The site of the study had just been cropped with tiger nuts without either organic or inorganic fertilizers.

3.4 Soil Sampling and Characterization

Soil samples were taken from the University's nursery site at depth between 0-30 cm and bulked. The soil is a Savannah Ochrosol type, which is derived from the Votaian sandstone within the Bediese series, which occurs on the upper and middle slopes of catena (F.A.O/UNESCO, Legend classification of soil 1990). The soil is characteristically deep yellowish-red sandy loam and free from stones and concretions. The soils were air dried, crushed and sieved through 2 mm mesh immediately after sampling. Samples were analysed for pH, texture, organic carbon, total nitrogen, ammonium nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K, and Na) and exchangeable acidity (H^+ and Al^{3+}).

3.5 Analytical Methods

The chemical and physical properties of the soils used were determined in the soil science laboratory of Soil Research Institute at Kwadaso Kumasi using standard procedures (Jackson 1974).

3.5.1 Soil pH

Soil pH was determined in a 1:2.5 suspension of soil and water using a H19017 microprocessor pH meter. A 20 g soil sample was weighed into 100 ml plastic bottle. To this 50 ml distilled water was added from a measuring cylinder and the bottle capped. The solution was shaken on a reciprocating shaker for thirty minutes. After calibrating the pH meter with buffer solutions at pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

3.5.2 Soil Organic Carbon

Soil organic carbon was determined by a modified Walkley and Black (1934) procedure as described by Nelson and Sommers (1982). This procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After reaction, the excess dichromate is titrated against ferrous sulphate. One gram of soil samples was weighed into an erlenmeyer flask. A reference sample and a blank were included. Ten millimeters of 1.0 N (equivalent to 0.1667 M) potassium dichromate solution was added to the soil and the blank flask. To this, 20 ml of concentrated sulphuric acid was carefully added from a measuring cylinder, swirled and allowed to cool for 30 minutes in a fume cupboard. Distilled water (250 ml) and concentrated orthophosphuric acid (100 ml) were added and allowed to cool. One millimeter of diphenylamine indicator was added and titrated with 1.0 M ferrous sulphate solution.

Calculation

The organic carbon content of the soil is:

$$\% \text{ organic carbon} = \frac{M \times 0.39 \times mcf\,(V1-V2)}{S}$$

Where

M = molarity of ferrous sulphate solution

V_1 = Ml ferrous sulphate solution required for blank

V_2 = Ml ferrous sulphate solution required for sample

S = weight of air – dry sample in grams

mcf = moisture correcting factor (100 + % moisture) / 100

0.39 = 3 x 0.001 x 100 % c 1.3 (3 = equivalent weight of C)

3.5.3 Total Nitrogen

The total nitrogen was determined by kjeldahl digestion and distillation procedure as described by Soil Survey Laboratory Method Manual (1996). A 0.5 g soil sample was put into a kjeldhl digestion flask and 5ml distilled water added to it. After 30 minutes, 5 ml concentrated sulphuric acid and selenium mixture were added and mixed carefully. The sample was heated on a kjeldhl digestion apparatus for 3 hours until a clear digest was obtained. The digest was diluted with 50 ml distilled water and mixed well until no more sediment dissolved and allowed to cool. The volume of the solution was made to 100 ml with distilled water and mixed well. A 2.5 ml aliquot of the solution was transferred to the reaction chamber and 10 ml of 40 % NaOH solution was added followed by distillation. The distillate was collected in 2 % boric acid. The distillate was titrated with 0.02 N HCl solutions with bromocresol green as indicator. A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water used.

Calculation

The % N in sample was expressed as:

$$\% \text{ N} = \frac{\text{M x (a-b) x 1.4 x mcf}}{\text{S}}$$

Where

M = concentration of HCl used in titration

a = ml HCl used in sample titration

b = ml HCl used in blank titration

s = weight of air – dry sample in grams

mcf = moisture correcting factor (100 + % moisture) / 100

1.4 = 14 x 0. 001 x 100 % (14 = atomic weight of nitrogen)

3.5.4 Available Phosphorus

The readily acid – soluble form of phosphorus of samples was extracted with a HCl: NH_4F mixture called the Bray's No. 1 method as described by Bray and Kurtz (1945) and Olsen and Sommers (1982), the phosphorus was then determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as reducing agent.

A 2.0 g sample was weighed into a shaking bottle (50 ml) and a 20 ml of extracting solution of Bray – 1 (0.03 M NH_4F and 0.025 M HCl) was added. The sample was spinned with a centrige for one minute and then immediately filtered through a fine filter paper (whatman No. 42). One ml of the standard series, the blank and the boric acid and 3 ml of coloring extract, 2 ml reagent (ammonium molybdate and antimony tartarate solution) were pipetted into a test tube and homogenized. The solution was allowed to stand for 10 min for the blue colour to develop to its maximum. The absorbance was measured on a Jenway 6715UV/Vis spectrophometer at 880 nm wavelength. A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6 mg P/L was prepared from a 12 mg/L stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/L in 100 ml volumetric flasks and made to volume with distilled water. Aliquots of 0, 1, 2, 3, 4, 5 and 6 ml of standard solution were put in 100 ml volume flasks and made to 100 mg P/L of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water.

Calculation:

$$P\ (mg / kg) = \frac{(a-b) \times 20 \times 6 \times mcf}{S}$$

Where:

a = mg / lP a sample extract

b = mg / lP in blank

s = sample weight in grams

mcf = moisture correcting factor

20 = ml extracting solution

6 = ml final sample solution

3.5.5 Available Potassium (K)

A 20 ml of the extract was used for the available K. The K values were determined using emission values of the Gallenkamp Flame analyzer. A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6.0 mg was prepared from a 12 mgP/L stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mgP/L in 100 ml volumetric flask and made to the volume with distilled water.

Calculation:

$$K\ (mg/kg) = \frac{(a-b) \times 20 \times 6 \times mcf}{S}$$

Where:

a= mg/LK in sample extract

b = mg/LK in blank

s = sample weight in grams

mcf = moisture correcting factor

20 = ml extracting solution

6 = ml final sampling solution.

3.5.6 Determination of Exchangeable Acidity (Al^{3+} and H^{+})

This consists of Aluminum and hydrogen. Five grams of soil sample was put into a shaking bottle and 100 ml of 1.0 M KCl solution added. The mixture was shaken for an hour and then filtered. Fifty milliliters portion of the filtrate was transferred into an Erlenmeyer flask and 2 – 3 drops of phenolphthalein indicator solution added. The solution was titrated with 0.05 M NaOH until the color just turned permanently pink. The amount of base used was equivalent to total acidity (H^{+}+Al^{3+}). A few drops of 0.05 M HCl were added to the same mixture to bring the solution back to colourless condition and 10ml of 1.0 M sodium fluoride (NaF) solution added. The solution was then titrated with 0.05 M HCl until the colour disappeared. The milli equivalents of acid used are equal to the amount of exchangeable Al. The amount of H was determined by the difference (McLean, 1965)

Calculation:

$$\text{Exchangeable Al + H or Al (Cmol−/Kg soil)} = \frac{0.05 \times V \times 200}{W}$$

Where:

0.05 = molarity of NaOH or HCl used for titration

V = ml NaOH or HCl used for titration

W = weight of air – dried soil sample in grams

3.6 Determination of Exchangeable Bases

Exchangeable bases (Ca, Mg, K, and Na) content in the soil were determined in 1.0 M ammonium acetate (NH_4OAc) extract (Black, 1965).

3.6.1 Extraction of the Exchangeable Bases

A 10 g sample was weighed into an extraction bottle and 100 ml of 1.0 M ammonium acetate solution was added. The bottle with its contents was shaken for an hour. At the end of the shaking the supernatant solution was filtered through No 42 whatman filter paper.

3.6.2 Determination of the Exchangeable Calcium

A 10 ml portion of the extract was transferred into an Erlenmeyer flask. To this, 10 ml of potassium hydroxide solution was added followed by 1.0 ml of triethanolamine. Few drops of potassium cyanide solution and few crystal of cal-red indicator were then added. The mixture was titrated with 0.02 M EDTA (ethylene diaminetetraacetic acid) solution from a red to a blue end point.

3.6.3 Determination of Exchangeable Calcium and Magnesium

A 10 ml portion of the extract was transferred into an Erlenmeyer flask and 5 ml of ammonium chloride – ammonium hydroxide buffer solution was added followed by 1.0 M of triethanolamine. Few drops of potassium cyanide and Eriochrome Black T solution were then added. The misture was titrated with 0.02 M EDTA solution from a red to a blue end point.

Calculation:

$$Ca + Mg \text{ (or Ca) (Cmol/kg soil)} = \frac{0.02 \times V \times 1000}{W}$$

Where:

W= weight in grams of soil extracted

V= ml of 0.02 M EDTA used in the titration

Concentration of EDTA used = 0.02 M

3.6.4 Determination of Exchangeable Magnesium

This was calculated by subtracting the value obtained from calcium alone from the calcium + magnesium value.

3.6.5 Determination of Exchangeable Potassium and Sodium

Potassium and Sodium in the soil extract were determined by flame photometry. Standard solution of 0, 2, 4, 6, 8 and 10 ppm K and Na were prepared by diluting appropriate volumes of 100 ppm K and Na solution to 100 ml in volumetric flask using distilled water. Flame photometer readings for the standard solutions were determined and a standard curve constructed. Potassium and Sodium concentrations in the soil extract were read for the curve.

Calculations:

$$\text{Exchangeable K (Cmol/Kg soil)} = \frac{\text{Graph reading} \times 100}{39.1 \times w \times 10}$$

$$\text{Exchangeable Na (Cmol/Kg soil)} = \frac{\text{Graph reading} \times 100}{23 \times w \times 10}$$

Where:

W = weight of air-dried sample soil in grams

39.1 = mole of potassium

23 = mole of sodium

3.6.6 Calculation of Effective Cation Exchange Capacity (ECEC)

It was calculated by the Sum of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity (Al and H).

3.7 Analysis of Animal Manures and Rock Phosphate

Rock phosphate, fresh samples of cow dung, poultry manure and pig manure were taken and analysed for P, Ca, Mg, K and N. The analysis was carried out using the methods described above.

3.7.1 Sources of Composting Materials

Rock phosphate for the study was obtained from Pure and Perfect Enterprise, Tema. The poultry manure was obtained from Sydals farm, Agyei Kojo near Ashaiman whiles pig and cattle manures were obtained from the University of Education Winneba animal farm.

3.7.2 Composting Procedures

Rock Phosphate (RP) was composted with poultry manure, cattle manure and pig manure to evaluate the effect of the manures on the release of P from the rock phosphate. A CRD with 12 treatments and 3 replicates was used in a pot experiment. Poultry manure, cattle manure, pig slurry and soil were used in their fresh state mixed with the rock phosphate. Two rates of application of the RP were used. That is 1 kg of RP to 2 kg of animal manure and 1 kg of RP to 3 kg of animal manure. The RP was weighed into 15 liter capacity plastic buckets. The appropriate weights of the organic manures or soil were added. The contents were thoroughly mixed, watered at regular intervals and allowed to stand in the shade for decomposition. The decomposition period lasted 84 days. At every three weeks, samples were taken for laboratory analysis for available phosphorus. After sampling, the phosphocompost was turned and watered to ensure effective decomposition and to maintain stable moisture. There were twelve treatments in all with each having three replicates

The treatments were:

- Sole Soil (control)
- Rock phosphate + Soil (1:2)
- Rock phosphate + Soil (1:3)
- Sole Poultry manure
- Rock phosphate + Poultry manure (1:2)
- Rock phosphate + Poultry manure (1:3)
- Sole Cow dung
- Rock phosphate + Cow dung (1:2)
- Rock phosphate + Cow dung (1:3)

- Sole Pig manure
- Rock phosphate + Pig manure (1:2)
- Rock phosphate + Pig manure (1:3)

During the decomposition period, the samples of treatments were analysed on the 0-day, 21st-day, 42nd-day, 63rd-day and on the 84th-day for levels of available phosphorus (Table 4.2).

3.8 Effect of Phosphocompost on the Plant Growth, Dry Matter Yield and Nutrient Uptake of Lettuce

After the laboratory experiment on P released which lasted 84 days, there was the need to assess the influence of phosphocompost on the growth, dry matter yield and NPK uptake by lettuce. A complete randomized design (CRD) with 12 treatments and three replicates was used in a pot experiment. Lettuce was used as a test crop. A 9.6 g of phosphocompost was weighed and added to 4.42 kg of soil. This was equivalent to 60 kg phosphocompost per hectare. This was allowed to stand for a week before transplanting. Three seedlings were planted at one seedling per hill. A 300 ml of water was applied between 2-3 days.

3.9 Cultural Practices and Field Observations

Seedlings were transplanted two weeks after emergence at a distance of 20 cm between plants and 20 cm between rows, giving a plant population of 250,000 stands per hectare. One plant was tagged for agronomic studies. Parameters studied included plant height, leave length, leave width and leave area, these started 14 days after planting (DAP) and continued at 7 days intervals for 49 days. Plant height was measured as the vertical distance between the ground and the highest living part of the plan. Leaf area was determined by measuring the length and width of all the leaves on a plant with a simple ruler and the average area was recorded as the leaf area (Ogbodo *et al.,* 2010). Weeds were handpicked as and when necessary.

3.10 Harvest and Plant Analysis

After six weeks of study the crops were harvested for further analysis. During biomass determination the fresh weights of whole plants were taken using the electronic weighing scale. The plant parts were then oven dried at 75 ^{0}C for 48 hours and weighed. The differences between the fresh and dry weights were recorded as the moisture contents. The dried plant parts (leaves stem and roots) were finely milled and analyzed for N.P. and K uptake by the methods described at 3.5.4

3.11 Soil Analysis after Lettuce Harvest

After harvesting the lettuce the soils in the pots were sampled at the depth of 30 cm for analysis, for P, NO_3^- -N, NH_4^+-N, exchangeable acidity (H^+, Al^{3+}) and exchangeable base (Ca, Mg, K and Na) using the procedures described above.

3.12 Data Analysis

Data was analysed by analysis of variance (ANOVA) procedures using GENSTAT statistical software 11th edition. Means separation was done using least significant difference (LSD) values.

CHAPTER FOUR

4.0 RESULTS

4.1 Some Chemical and Physical Properties of Compost Materials

The chemical composition and properties of the various materials used for the study are presented in tables 4.1a and 4.1b respectively

From Table 4.1a below, RP had the highest Ca content of 46.82 % whiles Pig manure had the least of 0.26 %. With regards to the contents of Mg, pig manure had the highest of 1.40 % whiles RP had the least of 0.03 %. The highest potassium content of 0.90 % was in PM whiles RP had the least of 0.02 %. The highest phosphorus content of 11.04 % was in RP whiles CM had the least of 0.71 %. The highest nitrogen content of 4.27 % was in PM whiles RP had the least of 0.04 %.

From Table 4.1b the soil used had the following chemical properties: pH (H_2O, 1:2.5)- 6.05, Organic carbon (%) - 1.12,Total Nitrogen (%) - 0.07, NO_3-N (mg/NKg-^{1})$^{-}$ 2.30, NH_4^+-N (mg Nkg^{-1})-16.03,Organic matter (%)- 0.8, Available P (Bray -1)(ppm)- 37.20, Bulk density g/cm^3- 1.70, Ca- 4.69, Mg - 1.22, K - 0.9 and Na - 0.06. The total exchange base - 6.87, Total Exchange Acidity (Al^{3+} + H^+) - 0.8 and CEC (meq/100 g) - 6.40.

Table 4.1a Some Chemical Composition of Rock Phosphate and Animal Manures used for the study.

	Ca %	Mg%	K%	P%	N%
Poultry manure (PM)	2.14	0.65	0.90	1.77	4.27
Cattle manure (CM)	1.98	0.64	0.26	0.71	2.06
Pig manure (PGM)	0.26	1.40	0.48	1.57	2.13
Rock Phosphate (RP)	46.82	0.03	0.02	11.04	0.04

Table 4.1b Some physical and chemical properties of the soil used

Property	Value
Chemical properties	
pH (H_2O, 1:2.5)	6.05
Organic. carbon (%)	1.12
Total N (%)	0.07
NO_3^- -N ($mgNkg^{-1}$)	2.30
NH_4^+-N (mgNkg-[1])	16.03
Org. matter (%)	0.8
Available P Bray -1(ppm)	37.20
Bulk density g/cm^3	1.70
Exchange bases (Me/100g)	
Ca^{+2}	4.69
Mg^{+2}	1.22
K^+	0.9
Na^+	0.06
Total exchange base	6.87
Total Exchange Acidity (Al^{3+} + H^+)	0.8
CEC (meq/100g)	6.40
Physical properties	
Sand (%)	58.00
Silt (%)	25.00
Clay (%)	17.00
Texture Class	Sandy-Loam soil

4.2 Effect of Composting on P Released from RP

Significant increases in available P concentration were observed when the organic manures were added to rock phosphate and composted (Table 4.2).

From Table 4.2, it could be seen that there was generally steady rise in P release from 0-day up until the 63rd day. Thereafter a steady decline in release was observed.

In all cases treatments 1:3 performed best in P released followed by treatments 1:2 and then the sole treatments.

Table 4.2 Released P during 84 days of composting

	Available P (mg/kg)				
Treatment	0 Day	21Days	42 Days	63 Days	84 Days
SOLE SOIL	0.11	0.16	0.22	0.22	0.21
RP + SOIL 1:2	0.14	0.22	0.27	0.28	0.27
RP + SOIL 1:3	0.17	0.25	0.29	0.32	0.24
SOLE CM	0.11	0.19	0.25	0.28	0.24
RP + CM 1:2	0.45	0.49	0.58	0.63	0.61
RP + CM 1:3	0.47	0.51	0.76	0.78	0.75
SOLE PM	0.21	1.02	1.92	1.98	1.96
RP + PM 1:2	0.49	2.55	3.97	4.06	3.92
RP + PM 1:3	0.58	2.75	4.08	4.76	3.98
SOLE PGM	0.13	0.32	0.48	1.03	1.02
RP + PGM 1:2	0.41	1.25	1.36	1.48	1.45
RP + PGM 1:3	0.43	1.31	1.47	2.03	2.02
LSD	0.03	0.03	0.03	0.02	0.02
% CV	5.0	1.1	0.8	0.6	0.6

RP = rock phosphate, CM = cattle manure, PM = poultry manure, PGM = pig manure.

4.2.1 Comparison between Sole Treatments of the Various Study Materials

Comparing the P released among the sole treatments (Table 4.2), it could be observed that the sole soil released the least P throughout the assessment period while sole PM released the highest P during the same period. There were significant differences ($p < 0.05$) in the P released among treatments within the days of assessment.

4.2.2 Comparison between Treatments 1:2 of the Various Study Materials

With regards to the P released by treatment combinations 1:2, all the manure-RP combinations performed better than the soil with the same treatment. The PM released the highest P throughout the study period, followed by PGM, CM and soil. Significant differences ($p < 0.05$) were observed among treatments within the days of assessment (Table 4.2).

4.2.3 Comparison between Treatments 1:3 of the Various Study Materials

Comparing the differences between treatment combinations 1:3 it was observed from Table 4.2 that PM released the highest P values throughout the study period, with the peak release of 4.76 mg/kg on the 63rd day. It could be observed that all the other study materials also had their highest performances on the same day. There were significant differences in P released ($p < 0.05$) among treatments within the days of assessment.

4.2.4 Comparison between Treatment Combinations 1:2 and 1:3 of Soil

Table 4.2 shows a general steady increase in P released from 0-day to the 63rd day. There was also a decline in P release from the 63rd to the 84th day. Treatment RP + soil 1:3 released higher values of P than treatment RP + soil 1:2 throughout the decomposition period. There were significant differences ($p < 0.05$) in P released among treatments within the days of assessment.

4.2.5 Comparison between Treatment Combinations 1:2 and 1:3 of Cattle Manure

There was a general steady increase in P release from 0-day to the 63rd day (Table 4.2). There was also a decline in P release from the 63rd to the 84th day. Treatment CM 1:3 released higher values of P than treatment CM 1:2 throughout the decomposition period. They had peak values of 0.78 mg/kg and 0.63 mg/kg respectively on the 63rd day. There were significant differences ($p < 0.05$) of P released among treatments within the days of assessment.

4.2.6 Comparison between Treatment Combinations 1:2 and 1:3 of Poultry Manure

Table 4.2 shows variations in peak P released between the two treatment ratios. Treatment RP + PM 1:3 released the highest P value of 4.76 mg/kg on the 63rd day, whiles RP + PM 1:2 on the other hand released comparatively lower P values throughout the period, with the peak value of 4.06 mg/kg on the 63rd day. There were significant differences between the ratios ($p < 0.05$) within the days of assessment.

4.2.7 Comparison between Treatment Combinations 1:2 and 1:3 of Pig Manure

Table 4.2 shows a general steady rise in values by treatment RP + PGM 1:3 from the 0-day to the peak value of 2.05 mg/kg on the 63rd day was observed after which a decline in P released was noted. Treatment RP + PGM 1:2 showed comparatively smaller values in P released from the 0- day to 63rd day to the peak of 1.45 mg/kg on the 63rd day. There were significant differences ($p< 0.05$) between the two treatment ratios within the days of assessment.

4.3. Effect of Phosphocompost on Lettuce Plant Height, Leaf Length, Leaf Width and Leaf Area.

The effects of the phosphocompost on lettuce plant height, leaf length, leaf width and leaf area are presented in Tables 4.3 to 4.6.

4.3.1 Plant Growth Parameters of Lettuce as Affected by Sole Treatment Materials.

The sole poultry manure (PM) treatment recorded the highest lettuce plant height, leaf length, leaf width and leaf area among the sole treatments. The sole soil treatment in most cases had significant ($p < 0.05$) the lowest recordings of the parameters.

4.3.2 Treatments 1:2 Ratios on Lettuce Growth Parameters.

From tables 4.3 - 4.6 it could be seen that the treatment combination of rock phosphate and the poultry manure (PM) recorded the highest lettuce plant height, leaf length, leaf width and leaf area among the 1:2 treatment ratios. All the manure combinations were significantly ($p < 0.05$) higher than the soil treatments.

4.3.3 Treatment 1:3 Ratios on the Lettuce Growth Parameters

From tables 4.3 - 4.6 it could be seen that the treatment combination of rock phosphate and the poultry manure (PM) recorded the highest lettuce plant height, leaf length, leaf width and leaf area among the 1:3 treatment ratios. All the manure combinations were significantly ($p < 0.05$) higher than the soil treatments. Poultry manure treatment RP + PM 1:3 consistently recorded the highest growth of lettuce throughout the six weeks growth period.

Observations from Tables 4.3 – 4.6 indicates that generally, all the treatments enhanced better growth of lettuce than the sole soil treatment (control). All treatment ratios of 1:3 had better results than the 1:2 and the sole treatments. Pig manure treatments (PGM) had poorer growth as compared to the cattle manures. Poultry manure treatments recorded better lettuce growth parameters with RP + PM 1:3 having the best.

Table 4.3 Effect of Phosphocompost on Plant Height of Lettuce (cm)

	Plant Height (cm)					
Treatments	**14 days**	**21 days**	**28 days**	**35 days**	**42 day**	**49 days**
Sole Soil	4.5	4.8	5.1	6.2	8.7	9.2
RP + Soil 1:2	4.7	5.8	5.9	6.4	11.5	11.8
RP + Soil 1:3	4.8	5.6	5.9	6.6	12.0	12.3
Sole CM	5.0	5.7	6.2	6.4	15.3	15.7
RP + CM 1:2	5.3	6.5	6.8	7.2	15.3	15.7
RP + CM 1:3	5.4	7.1	7.6	8.4	16.6	16.8
Sole PM	5.5	7.8	7.9	9.5	18.4	18.8
RP + PM 1:2	5.7	8.1	11.7	15.7	19.5	21.3
RP + PM 1:3	5.8	8.3	14.9	19.2	21.3	21.6
Sole PGM	5.1	6.3	7.1	9.2	11.2	11.61
RP + PGM 1:2	5.2	6.4	7.2	9.6	12.2	12.41
RP + PGM 1:3	5.3	6.7	7.4	9.8	12.3	12.5
LSD	0.3	0.4	0.2	0.2	0.2	0.5
CV%	1.9	0.5	0.9	0.1	0.0	0.3

DAP = **days after planting**

Table 4.4 Effect of Phosphocompost on Leaf Length of Lettuce (cm)

	Leaf Length (cm)					
Treatments	**14 days**	**21 days**	**28 days**	**35 days**	**42 days**	**49 days**
Sole soil	3.3	4.3	5.1	7.1	7.3	5.4
RP + Soil 1:2	3.5	4.7	5.3	8.4	8.6	8.8
RP + Soil 1:3	4.0	5.0	9.3	9.5	11.2	11.4
Sole CM	4.3	4.6	6.7	11.9	14.3	14.5
RP + CM 1:2	4.5	5.0	10.0	14.4	15.1	15.4
RP + CM 1:3	4.7	5.0	10.7	15.4	15.6	17.3
Sole PM	4.5	5.1	6.1	16.1	16.7	17.3
RP + PM 1:2	4.8	6.0	12.6	16.3	17.1	17.6
RP + PM 1:3	5.1	6.1	13.7	17.3	17.2	17.8
Sole PGM	4.2	4.7	4.9	6.2	8.2	8.4
RP +PGM 1:2	4.3	5.0	5.6	6.6	8.3	8.6
RP +PGM 1:3	4.4	5.1	5.7	6.9	8.5	8.8
LSD	0.2	0.3	0.3	2.3	0.2	1.9
CV%	2.3	1.2	0.6	5.1	0.5	3.1

DAP = days after planting

Table 4.5 Effect of Phosphocompost on Leaf Width of Lettuce (Cm)

	Leaf width (cm)					
Treatments	**14 days**	**21 days**	**28 days**	**35 days**	**42 days**	**49 days**
Sole Soil	0.7	1.0	2.0	2.7	3.3	3.4
RP + Soil 1:2	0.8	1.0	2.1	3.2	4.1	4.3
RP + Soil 1:3	0.8	1.1	2.4	3.4	4.2	4.5
Sole CM	1.0	1.0	2.1	4.1	4.4	5.0
RP + CM 1:2	1.0	1.4	3.0	4.2	5.0	5.4
RP + CM 1:3	1.0	1.6	3.3	5.0	5.2	5.4
Sole PM	1.0	1.6	2.5	5.0	7.0	7.4
RP + PM 1:2	1.0	1.7	3.9	6.7	8.0	8.0
RP + PM 1:3	1.0	1.9	4.1	7.0	8.5	8.7
Sole PGM	1.0	1.3	2.4	2.6	4.1	4.1
RP + PGM 1:2	1.0	1.4	2.7	3.0	4.2	4.3
RP + PGM 1:3	1.0	1.5	2.8	3.5	4.3	4.4
LSD	0.1	0.1	0.1	0.1	0.2	0.1
CV%	1.0	1.0	1.0	0.8	0.6	1.8

DAP = days after planting

Table 4.6 Effect of Phosphocompost on Leaf Area of Lettuce (cm^2)

	Leaf Areal (cm^2)					
Treatments	**14 days**	**21 days**	**28 days**	**35 days**	**42 days**	**49 days**
Sole Soil	2.4	4.3	10.2	19.1	24.1	26.2
RP + Soil 1:2	2.7	4.7	11.1	28.1	36.1	40.5
RP + Soil 1:3	3.2	5.7	22.8	30.1	45.9	49.0
Sole CM	4.3	4.6	14.1	48.8	71.5	73.0
RP + CM 1:2	4.5	7.0	30.0	60.5	72.8	82.7
RP + CM 1:3	4.7	8.0	35.3	76.8	79.0	89.1
Sole PM	4.5	8.1	15.3	81.7	117.0	128.0
RP + PM 1:2	4.8	9.6	49.1	109.4	136.9	140.8
RP + PM 1:3	5.1	11.7	56.2	120.7	146.2	155.5
Sole PGM	4.2	6.1	11.8	18.5	33.6	34.7
RP + PGM 1:2	4.3	7.0	15.4	19.8	34.4	37.8
RP + PGM 1:3	4.4	7.7	15.5	20.7	35.7	38.7
LSD	0.3	0.4	0.8	9.0	5.2	2.4
CV%	2.3	0.7	0.6	4.3	2.8	2.8

DAP = days after planting

4.4 Effect of Phosphocompost on Lettuce Fresh and Dry Weights

4.4.1 Fresh Weight

Comparing the fresh weights of lettuce from the treatments in Table 4.7, it could be seen that crops planted on the RP + PM 1:3 treatment weighed the highest (270.87 g/plant) while those planted with the sole soil treatment weighed the lowest (45.20 g/plant). Among the ratio 1:2, treatment RP + PM 1:2 weighed the highest (199.6 g/plant) while treatment RP + Soil 1:2 weighed the lowest (58.63 g). With regards to the ratio 1:3, treatment RP + PM 1:3 recorded the highest weight (270.87 g/plant) while treatment RP

+ soil 1:3 recorded the least weight (84.03 g/plant).Among the soil treatments the RP + Soil 1:3 treatment had the highest fresh weight value (84.03 g/plant) while the sole soil treatment recorded the lowest value (45.2 g/plant).Treatment RP + CM 1:3 recorded the highest fresh weight (154.60 g/plant) while sole CM gave the lowest (106.9 g/plant) among the CM treatments. Among the poultry manure treatments, treatment RP + PM 1:3 recorded the highest fresh weight value (270.87 g/plant) while treatment sole PM recorded the lowest (131.6 g/plant). Treatment RP + PGM 1: 3 recorded the highest fresh weight value (171.73 g/plant) while the sole treatment the PGM recorded the lowest value of 126.63 g within the PGM treatments. There were significant differences ($p < 0.05$) among the fresh weights.

Table 4.7 Effects of Phosphocompost on Fresh and Dry Weights of Lettuce

Treatments	**FWT (g)/plant**	**DWT (g)/plant**	**MTC (g)/plant**
Sole soil	45.20	9.00	36.20
RP + soil 1:2	58.63	10.57	48.06
RP + soil 1:3	84.03	15.23	68.80
Sole CM	106.90	18.17	88.73
RP + CM 1:2	151.63	25.80	125.83
RP + CM 1:3	154.60	26.27	128.33
Sole PM	131.60	32.63	98.97
RP + PM 1:2	199.60	49.93	149.67
RP + PM 1:3	270.87	67.70	203.17
Sole PGM	126.63	18.97	107.66
RP + PGM 1:2	166.30	24.77	141.53
RP + PGM 1:3	171.73	25.73	146.00
LSD	6.01	1.43	8.52
% CV	1.9	2.0	4.3

RP = rock phosphate, CM = cattle manure, FWT=fresh weight, MTC= moisture content, PM = poultry manure PGM = pig manure, DWT= dry weight

4.4.2 Dry Weight

Table 4.7 generally showed that treatment RP + PM 1:3 recorded the highest dry weight (67.70 g/plant) of lettuce while the sole soil treatment recorded the least value (9.00 g/plant) Among the sole treatments the sole PM treatment had the highest dry weight (32.63 g/plant) value while lettuce planted with the sole soil treatment weighed the lowest (9.00 g/plant). Among the ratio 1:2, treatment RP + PM 1:2 weighed the highest (49.93 g/plant) whiles treatment RP + Soil 1:2 weighed the lowest (10.57 g/plant). With regards to the ratio 1:3, treatment RP + PM 1:3 recorded the highest dry weight (67.70 g/plant) while treatment RP + soil 1:3 recorded the least weight value (15.23 g/plant). Within the soil treatments, treatment RP + Soil 1:3 gave the highest dry weight value (15.57 g/plant) while the sole soil treatment gave the lowest value (9.00 g/plant). Treatment RP + CM 1:3 recorded the highest dry weight value (26.27 g/plant) while sole CM recorded the lowest value (18.17 g/plant) among the CM treatments. Treatment RP + PM 1:3 recorded the highest dry weight value of (67.70 g/plant) while the sole PM treatment recorded the lowest value of (32.63 g/plant) within the PM treatments. Treatment RP + PGM 1: 3 recorded the highest dry weight value (25.73 g/plant) while the sole PGM treatment recorded the lowest dry weight value (18.97 g/plant) of lettuce among the PGM treatments.

4.4.3 Moisture Content

Table 4.7 generally showed that treatment RP + PM 1:3 recorded the highest lettuce moisture content of 203.17 g/plant while the sole soil treatment recorded the least lettuce moisture content of 36.20 g/plant. Among the sole treatments lettuce planted on the sole PM treatment had the highest moisture content of 98.97 g/plant while lettuce on the sole soil treatment had the lowest of 36.20 g/plant. Among the ratio 1:2, treatment RP + PM 1:2 had the highest lettuce moisture content (149.67 g/plant) while treatment RP + Soil 1:2 had the lowest of 48.06 g/plant. With regards to the ratio 1:3, treatment RP + PM 1:3 recorded the highest lettuce moisture content of 203.17 g/plant while treatment RP + soil 1:3 recorded least of 68.80 g/plant. Treatment RP + Soil 1:3 had the highest lettuce moisture content (68.80 g/plant) while the sole soil treatment had the lowest of 36.20 g/plant among the soil treatments. Treatment RP + CM 1:3 recorded the highest of 128.33 g/plant while sole CM weighed the lowest of 88.73 g/plant among the CM treatments. Treatment RP + PM 1:3 recorded the highest lettuce moisture content of 203.17 g/plant while sole PM treatment recorded the lowest of 98.97 g/plant among the PM treatments. Treatment RP + PGM 1: 3 recorded the highest lettuce moisture content (146.00 g/plant) while the sole PGM treatment recorded the lowest of 107.66 g/plant among the PGM treatments.

4.5 Nitrogen, phosphorus and potassium content of lettuce.

Table 4.8 shows the contents of Nitrogen, Phosphorus and Potassium in the lettuce plant as influenced by the application of the phosphocompost.

Table 4.8 Percentages of NPK in Plant after Harvesting

	Nutrient content of lettuce (%)		
Treatments	**N**	**P**	**K**
Sole soil	0.33	0.31	0.25
RP + soil 1:2	0.37	0.42	0.49
RP + soil 1:3	0.39	0.45	0.76
Sole CM	0.36	0.34	0.98
RP + CM 1:2	0.53	0.46	1.11
RP + CM 1:3	0.56	0.49	1.24
Sole PM	0.77	0.59	1.76
RP + PM 1:2	0.81	0.66	2.18
RP + PM 1:3	0.99	0.82	2.43
Sole PGM	0.48	0.49	1.02
RP + PGM 1:2	0.56	0.57	1.14
RP + PGM 1:3	0.64	0.58	1.35
LSD	0.02	0.02	0.02
% CV	0.3	0.7	0.3

RP = rock phosphate, CM = cattle manure, PM = poultry manure, PGM = pig manure

4.5.1 Nitrogen (N) Content

From Table 4.8, treatment RP + Soil 1:3 recorded the highest N value of 0.39 % while the sole soil treatment recorded the lowest N value of 0.33 % among the soil treatments. With cattle manure, the sole CM treatment recorded the lowest N value of 0.36 % while treatment RP + CM 1:3 recorded the highest N value of 0.56 %. With regards to poultry manures, the sole PM treatment recorded the lowest N value of 0.77 %, while treatment

RP + PM 1:3 recorded the highest N value of 0.99 %. With pig manure, the sole PGM treatment recorded the lowest N value of 0.48 % while treatment RP + PGM 1:3 recorded the highest N value of 0.64 %. Among the sole treatments the sole soil treatment recorded the lowest N value of 0.33 % while the sole PM treatment recorded the highest value of 0.77 %. With regards to the ratio 1:2, RP + soil 1:2 recorded the lowest value of 0.37 % while RP + PM 1:2 recorded the highest (0.81 %). For the ratio 1:3, treatment RP + soil 1:3 recorded the lowest value of 0.39 % while treatment RP + PM 1:3 recorded the highest value of 0.99 %.

4.5.2 Phosphorus (P) Content

Comparing the soil treatments, treatment RP + Soil 1:3 recorded the highest P value of 0.45 % while the sole soil treatment recorded the lowest P value of 0.31 %. With cattle manure, the sole CM treatment recorded the lowest P value of 0.34 % while treatment RP + CM 1:3 recorded the highest value of 0.49 %. With regards to poultry manure, the sole PM treatment recorded the lowest P value of 0.59 % while treatment RP + PM 1:3 recorded the highest P value of 0.82 %. With pig manure, the sole PGM treatment recorded the lowest P value of 0.49 % while treatment RP + PGM 1:3 recorded the highest P value of 0.58 %. Among the sole treatments the sole soil treatment recorded the lowest P value of 0.31 % while the sole PM treatment recorded the highest value of 0.59 %. With regards to the ratio 1:2, RP + soil 1:2 recorded the lowest value (0.42 %) while RP + PM 1:2 recorded the highest of 0.66 %. For the ratio 1:3, treatment RP + soil 1:3 recorded the lowest value (0.45 %) while treatment RP + PM 1:3 recorded the highest value of 0.82 %.

4.5.3 Potassium (K) Content

Comparing the soil treatments, treatment RP + Soil 1:3 recorded the highest K value of 0.76 %, while the sole soil treatment recorded the lowest value of 0.25 %. With cattle manure, the sole CM treatment recorded the lowest value of 0.99 % while treatments RP + CM 1:3 recorded the highest value of 1.24 %. With regards to poultry manure, the sole PM treatment recorded the lowest value of 1.76 % while treatment RP + PM 1:3 recorded the highest value of 2.43 %. With pig manure, the sole PGM treatment recorded the lowest value of 1.02 % while treatment RP + PGM 1:3 recorded the highest K value of 1.35 %. Comparing the sole treatments, the sole soil treatment recorded the lowest K value of 0.25 %, while the sole PM recorded the highest K value of 1.76 %. With regards to the ratio 1:2, RP + soil 1:2 recorded the lowest K value of 0.49 % while RP + PM 1:2 recorded the highest K value of 2.18 %. For the ratio 1:3, treatment RP + soil 1:3 recorded the lowest K value of 0.76 % while treatment RP + PM 1:3 recorded the highest with 2.43 %.

4.6 Some Soil Chemical Properties after Lettuce Harvest

Chemical Composition of the soil after harvesting of the lettuce plants are presented in table 4.9.

4.6.1 pH

There were slight differences between the various study materials. The sole soil treatment recorded the least pH value of 6.06 while RP + soil 1: 3 recorded the highest pH value of 6.18 among the soil treatments. The same trend was observed among the three manure treatments. Treatment RP + PM 1:3 recorded the highest pH value of 6.98

4.6.2 % Organic carbon

Treatments RP + PM 1:3 had the highest organic carbon value of 1.33 % while the sole soil treatment recorded the lowest value of 0.73 %. Treatment 1:3 recorded higher organic carbon values than treatments 1:2 among all the study materials.

4.6.3 Total % N

Treatment RP + PM 1:3 recorded the highest % N value of 0.17 % while the sole soil treatment had the lowest of 0.06 %. Treatment ratio 1:3 recorded higher % N values than treatment ratio 1:2 among all the materials.

4.6.4 % Organic Matter

The sole soil treatment recorded the lowest organic matter value of 1.24 % whiles five other treatments namely RP + CM 1:2, RP + CM 1:3, PM alone, RP + PM 1:2 and RP + PM 1:3 recorded the highest values of 2.0 % each.

4.6.5 Calcium

Treatment RP + PM 1:3 had the highest Calcium value of 7.25 % while the sole soil treatment had the lowest value of 4.71 %. However, the differences were not significant between the study materials.

4.6.6 Magnesium

The sole soil treatment and the sole PGM treatment recorded the lowest Mg values of 1.34 % each while treatment RP + PM 1:3 recorded the highest value of 5.45 %.

4.6.7 Potassium

The highest K value of 0.36 % was recorded by treatment RP + PM 1:3 while the sole soil treatment recorded the lowest value of 0.10 %.

4.6.8 Sodium

The sole soil treatment recorded the lowest Na value of 0.06 % while treatment RP + PM 1:3 recorded the highest Na value of 0.12 %. All the other treatments recorded higher Na values than the sole soil values.

4.6.9 Total Exchangeable Bases

The sole soil treatment recorded the lowest TEB value of 6.30 % while treatment RP + PM 1:3 recorded the highest value of 12.23 %. Treatment ratio 1:3 recorded higher TEB values than the ratio 1:2 among each study material.

4.6.10 Exchangeable Acidity

The sole soil treatment recorded the highest exchangeable acidity value of 0.6 while treatment RP + PM 1:3 recorded the lowest value of 0.16.

4.6.11 CEC Meq/100 g

The sole soil treatment recorded the lowest CEC value of 6.38 meq/100 g while treatment RP + PM 1:3 recorded the highest CEC value of 10.02 meq/100 g. Treatment ratios 1:3 recorded the highest values than their respective ratios 1:2.

4.6.12 Base Saturation

The highest base saturation value of 99.98 % was recorded by treatment RP + PM 1:3 while the sole soil treatment recorded the lowest value of 98.42 %.

4.6.13 Nitrate

The highest NO_3 value of 4.40 mg/kg was recorded by treatment RP + PM 1:3 while the sole soil treatment recorded the lowest value of 1.02 NO_3

4.6.14 Ammonium

The highest NH_4^+ value of 35.04 mg/kg was recorded by treatment RP + PM 1:3 while sole soil treatment recorded the lowest value of 18.04 mg/kg.

4.6.15 Available phosphorus (ppm)

The highest Available P value of 154.08 ppm was recorded by treatment RP + PM 1:3 while the sole soil treatment recorded the lowest value of 38.20 ppm.

TABLE 4.9: Effect of Treatments on Soil Chemical Properties

Treatment	pH(H_2O) 1:25	Org. C %	Total N %	Org M%	Exchangeable Cation Me/100g				TEB	Exchangeable Acidity Al + H	CEC Meq/100g	Base Sat. %	Micro Nutrient Ppm Element Dry Matter		Available Blay Ppm P
					Ca	Mg	K	Na					NO_3^-N mg/kg	NH_4^- mg/kg	
Sole soil	6.01	0.73	0.06	1.24	4.71	1.34	0.11	0.06	6.30	0.60	6.21	98.42	1.02	18.04	38.20
RP + soil 1:2	6.15	1.02	0.10	1.71	4.82	1.68	0.15	0.08	7.98	0.50	6.41	98.76	1.05	19.01	38.22
RP + soil 1:3	6.18	1.08	0.11	1.76	5.61	2.14	0.18	0.9	7.99	0.50	8.08	98.82	1.08	19.05	64.24
Sole CM	6.02	0.76	0.09	1.29	4.80	1.35	0.11	0.06	6.35	0.55	6.43	98.46	2.23	18.08	38.54
RP + CM 1:2	6.36	1.16	0.12	2.00	6.66	2.65	0.16	0.08	6.59	0.10	8.69	98.97	2.36	18.18	98.84
RP + CM 1:3	6.42	1.17	0.14	2.00	6.72	2.74	0.18	0.10	9.65	0.11	8.73	98.91	2.40	29.62	98.89
Sole PM	6.12	0.82	0.12	2.00	5.22	1.56	0.16	0.08	9.70	0.10	6.58	98.89	4.38	20.13	97.86
RP + PM 1:2	6.93	1.17	0.13	2.00	6.41	3.74	0.23	0.10	10.48	0.14	9.53	99.90	4.39	20.59	145.04
RP + PM1:3	6.98	1.33	0.17	2.00	7.25	5.42	0.36	0.13	12.23	0.16	10.02	99.98	4.40	35.04	154.08
Sole PGM	6.03	0.77	0.07	1.23	4.81	1.36	0.12	0.07	6.35	0.15	6.41	98.44	3.31	20.98	38.25
RP + PGM 1:2	6.78	0.96	0.10	1.66	5.37	3.21	0.20	0.10	8.84	0.10	8.91	99.21	3.36	22.75	41.25
RP + PGM 1:3	6.83	0.99	0.12	1.71	5.38	3.23	0.22	0.12	8.76	0.12	8.96	99.26	3.39	23.73	41.29

CHAPTER FIVE

5.0 DISCUSSION

5.1 Chemical and Physical Properties of Compost Materials

From Table 4.1a it could be said that based on the findings of Combs *et al*.(1998) the contents of Calcium, Magnesium, Potassium, Phosphorus and Nitrogen in the manures used were so low. They found that the ideal contents of Ca, Mg, K, P and N in poultry manure for example are 191.9, 10.0, 55.4, 90.4 and 94.4 respectively (Appendix A). The Togo Rock Phosphate used can also be classified as having a low potential to release P when applied directly based on the three fold classification of Diamond (1979) hence the need to compost it with animal manure.

The soil used in the study was sandy loam and slightly acidic. The exchangeable bases, total nitrogen and CEC (Table 4.1b) were low compared to the fertility requirements for lettuce cultivation stated by Okorie *et al*. (2010). According to the Soil Survey Laboratory Methods Manual of United States Department of Agriculture (1999), the chemical properties of the soil used as recorded in Table 4.1b, did not meet the requirements for lettuce cultivation, hence the need to apply the phosphocompost to improve the status of physical and chemical properties of the soil.

5.2 Effect of Composting on P Released from RP

Significant increases in available P concentration were observed (Table 4.2) when the organic manures and soil were added to rock phosphate and composted. The release of P during the period of decomposition could be attributed to the organic materials undergoing intensive microbial activities to release organic acids (Biswas and Narayanasamy, 2006). These organic acids in turn solubilized the RP to release P (Zaidic *et al.,* 2006).

Generally a steady rise in P released was observed in all treatments from 0-day up until the 63rd day. The ability of organic manure in enhancing the release of available P from RP has been related to increase in microbial activities and the acidic soil conditions created by the decay of the organic manure (Kim *et al.,* 1997). P release showed a steady decline after the peak performance on the 63rd day. This might be due to reasons including but not limited to the demise of some microbes caused by either insufficiency of available substrate (food) or some super class of microbes preying upon the weaker class of microbes in the pots, or that more energy was required by the population of microbes to effect decomposition and that more phosphorus will be required to build up ATP to enhance effective biological process of decomposition thus, there was immobilization of P (Ragavedra *et al*., 2009).

In all cases treatments ratios 1:3 performed best in P released followed by treatments ratios 1:2 and then the sole treatments. This suggests that the quantity of manure used might have influenced the increase of microbial population and consequently the quantity of P released. Different organic materials will create different soil environmental conditions (Nair and Ngouajio, 2012) and hence leading to differences in the release of available P from RP in soil amendments. Such situations might be the reasons behind the significant performance of the PM in enhancing higher release of available P in the amendments than the rest of the organic materials, because PM has been found to produce higher microbial biomass and hence acidic conditions in soil amendments (Lin *et al.*, 2010). Work by Blackwell *et al.* (2014) found that increasing rate of manure in phosphocomposting increases available phosphorus. In a similar study using palm oil mill effluent, the release of available P from RP was found to increase with the application of the effluent and the amount applied (Oviasogie and Uzoekwe, 2011).

5.3 Effect of Phosphocompost on the Growth, Dry Matter Yield and Nutrient Uptake of Lettuce

5.3.1 Plant growth

From Tables 4.4- 4.7, it could be seen that treatment RP + PM 1:3 maintained the lead in all the parameters taken throughout the study period while the sole soil treatment recorded the least performance. This could be attributed to the absorption and utilization of P and other nutrients at different levels in the various treatments It could be deduced from the data that the application of the phosphocompost influenced the uptake of nutrients and the consequent growth of lettuce. Lower growth parameters were recorded in the control plant which explains that the application of the phosphocompost has increased the nutrient content of the soil and thus influenced the growth parameters of lettuce plants.

Significant growths were observed in RP manure combinations, especially by the RP + PM 1:3 as compared to the rather low growth of the sole soil treatment. Aside the provision of soil nutrients, it could be that the application of phosphocompost might have resulted in lowering the bulk density, improved porosity and drainage and hydraulic conductivity and also lowered soil temperatures as Utobo et al. (2010) observed as conducive conditions for good lettuce growth.

Poor growth of lettuce crops planted on the sole soil treatment was observed. This could have resulted from the observed poor soil physical and chemical properties (Table 4.1b). Low organic matter content of the sole soil might have affected the growth performance of the lettuce crop. Organic matter is undoubtedly the store of soil nutrients and by implication a determinant of the soil buffer capacity (John, 2016). The lower levels of organic matter observed in the sole soil might have adversely affected the fertility of the soil and led to the comparatively lower lettuce crop productivity.

5.3.2 Effects of phosphocompost on fresh and dry weights of lettuce

From Table 4.7, treatment ratios 1:3 recorded higher fresh weights and dry weights values of lettuce. Treatment ratios 1:2 recorded the next highest values. RP + PM 1:3 recorded the highest fresh weight and dry weight values while the sole soil treatment recorded least weight. There was significant difference ($p<0.05$) between the RP + PM 1:3 and sole soil treatments during the study period.

It could be deduced from the data that the application of phosphocompost of different combinations significantly ($p < 0.05$) influenced the growth and increased the biomass of lettuce. Lower weights were recorded in the control plants. This explains that the application of phosphocompost increased the nutrient content of the soil and thus influenced the growth and dry matter yield of lettuce plants. These results are in agreement with Mishra *et al.* (1984) who found that phosphocomposting was effective in increasing dry matter yield.

5.3.3 Percentage of N. P. and K. in lettuce plant

The results in Table 4.8 show that phosphocompost application significantly ($p < 0.05$) influenced the uptake N, P and K. The results also showed that there were significant differences between treatment ratios in the order 1:3 > 1:2 > sole treatment. This suggests that the amount of the treatment material had a corresponding effect on nutrient uptake. This confirms the findings of a similar work by Agyarko *et al.* (2016). RP + PM 1:3 had the highest percentage values of each of the nutrients N, P and K. The application of the phosphocompost influenced the uptake of N, P and K and subsequently influenced their usage for growth and development of lettuce.

5.4 Effect of Treatments on soil Chemical Properties

5.4.1 pH

The RP +PM 1:3 and the other rock phosphate + Organic materials treatments recorded slightly higher pH values than the control. This suggests that the phosphocompost applied helped to release other elements which contributed to the increase in the pH of the soil. This confirms the findings of Tisdale *et al*. (1990) that organic matter adds basic plant nutrients to the soil which may raise the pH of the soil. This also agrees with a similar work by Mokolobate and Haynes (2002) who found that additions of organic residues increased the pH in the soil in the order PM > filter cake > house hold compost > grass residue.

5.4.2 Percentage Organic Carbon

Soil organic carbon (SOC) is considered a promising target for long-term carbon sequestration (Reynaldo *et al.,* 2012). From Table 4.9 treatment RP + PT 1:3 had the highest value of 1.33 % while the sole soil treatment recorded the lowest value of 0.73 %. There was significant improvement of soil organic carbon condition resulting from the application of the phosphocompost. There were differences in SOC in the order 1:3 > 1:2 > sole treatments and PM >PGM >CM > sole treatment. This confirms the finding of Grichs (1990) that differences in SOC is due to the kind of organic manure used.

5.4.3 Total Nitrogen

The application of the phosphocompost might have increased the organic matter content levels. In this work NH_4^+ - N, and NO_3-N were found to be higher in the phosphocompost treated soils than in the sole soil. The increase in the nitrogen content may be attributed to the quantity of organic manure used for the soil amendment which has resulted in increase in the nitrogen levels of the soil. This agrees with Wong *et al*. (1999).

5.4.4 Percentage Organic Matter

It could be seen from Table 4.9 that there was improvement of soil organic matter in the amended soil over the soil used in varying quantities as a result of phosphocompost application. This corroborates the findings of Eghball *et al.* (2002) who observed significant soil organic matter levels in plots amended with organic manure. Phosphocompost applied at different ratios had a corresponding increase in the organic matter and nutrient contents of the soil. This agrees with a study by McConnell *et al.,* (1993) who reported that compost applied at varying rates produce corresponding increases in soil organic matter.

5.4.5 Other Elements (Calcium, Magnesium and Sodium)

From Table 4.9 treatments RP + PT 1:3 had the highest Ca, Mg and Na values while the sole soil treatments had the lowest corresponding value of the elements . Compared to their corresponding values in the soil used, it is evident that the phosphocompost applied has helped to improve the Ca, Mg and Na contents of the soil as stated by Jun-Hua *et al.* (2007) that the addition of organic matter helps to enhance the contents of Ca^{2+}, Mg^{2+}, K^+ and Na^+ in the soil. This agrees with Hue (1988) who said one of the benefits of the use of composts and manures over inorganic fertilizers is their ability to provide non-NPK nutrients. Warman and Cooper (2000) also found that the application of composted poultry manure on soil increased soil nutrient levels.

5.4.6 Total Exchangeable Bases (TEB)

TEB is the sum of the bases (Ca, Mg, K, and Na) attached to the clay and organic constituents of soils and which can be exchanged with each other and with other positively charged ions in the soil solution. From Table 4.9 the sole soil treatment recorded the lowest TEB value while treatment RP + PM 1:3 recorded the highest TEB value. This suggests that phosphocompost application helped to increase the humus content of the amended soil. This confirm the work of Reeuwijk (2002) who concluded that humus, the end product of decomposed organic matter has the highest CEC values because organic matter colloids have large quantities of negative charges. This charge provides sites for elemental exchanges and to hold nutrients to improve soil fertility. Treatments with higher TEB values will have higher CEC values hence greater capacity to retain soil nutrients.

5.4.7 Exchangeable Acidity (EA)

From the Table 4.9 the sole soil treatment recorded the highest EA value while treatment RP + PM 1:3 recorded the lowest EA value. This is an indication that the application of the phosphocompost have resulted in reducing the EA of the amended soils over the sole soil. This is in conformity with the findings of Onwuka *et al*. (2016) who found that the application of lime + manure increase soil pH and reduce the exchangeable acidity of the amended soils over the control.

5.4.8 CEC Meq/100 g

From the Table 4.9 the sole soil treatment recorded the lowest value of 6.21Meq/100 g while treatment RP + PM 1:3 recorded the highest value of 10.02Meq/100 g. All other treatments showed an increase in the value of CEC over the sole soil treatment. This might have helped in holding and retaining cations in the soil against leaching and thus improving the nutrient condition of the soil. A study by McConnell *et al.*,(1993) concluded that applying compost would increase the CEC of most minerals in soils used for agriculture by a minimum of 10 %.

5.4.9 Base saturation BS (%)

It is the fraction of exchangeable cations that are base cations (Ca, Mg, K and Na). The concept of base saturation is important, because the relative proportion of acids and bases on the exchange sites determines the soil's pH. As the number of Ca^{++} and Mg^{++} ions replaces acidic hydrogen and aluminium cations base saturation is increased and the pH is raised (Mengel, 2008). From Table 4.9 the highest BS value of 99.98 % was recorded by treatment RP + PM 1:3 while the sole soil treatment recorded the lowest value of 98.42 %. The figures compared give an indication that base saturation content of the soil has improved as a result of the application of the phosphocompost. The higher the base saturation value the easier the acidity can be neutralized in the shortest time (Reeuwijk, 2002).

5.4.10 Available phosphorus (AP)

This is the phosphorus that is readily available in the soil for plant use. The highest value of 154.08ppm was recorded by treatment RP + PM 1:3 while the sole soil treatment recorded the lowest value of 38.20 ppm.The application of the phosphocompost significantly improved the AP content of the soil as can be seen from Table 4.9. This confirm a statement by Habib *et al.* (1999) that an increase in the agronomic effectiveness of RP in phosphocompost over direct application of RP can be expected because it make citric-soluble P content more available to plants.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The experiments were conducted in 2013 cropping season at the University of Education Winneba, Faculty of Agriculture research field in Mampong Ashanti in the forest transitional zone of Ghana on the Bediase series to evaluate the effectiveness of three livestock manures and soil on the dissolution of Togo rock phosphate to release phosphorus, assess the effect of phosphocompost on the growth and yield of lettuce and assess the residual effect of the phosphocompost on soil nutrient.

The treatments used were sole composting material, RP + composting material 1:2 and RP + composting material 1:3. The composting materials used were; soil, cattle manure, poultry manure and pig manure. The total numbers of treatments were twelve (12). These were laid out in a complete randomized design (CRD) with 3 replicates.

A kilogram of Togo Rock Phosphate was mixed with either two or three kilograms of the study materials and composted for 84days in a plastic bucket. During the composting period samples of phosphocompost were taken for laboratory analysis every two weeks to assess the levels of phosphorus released. After composting a 9.6 g of phosphocompost was weighed and added to 4.42 kg of soil. This was allowed to stand for a week before transplanting. Plant parameters studied were plant height, leaf length, leaf width leaf area and plant weight. Levels of soil nutrients were also assessed post planting. The peak of P releases were observed on the 63rd day, with the highest release occurring in RP + PM

1:3. Best performance of P release between the treatment ratios were in the order 1:3 > 1:2 > sole material. While best performance of P release between the composting materials were in the order poultry manure > pig manure > cattle manure >soil. It was established from the study that phosphocompost application significantly affected the growth and yield of lettuce and N, P and K uptake. Treatment RP + PM 1:3 were significantly ($p < 0.05$) higher throughout the growing period than the other amendments and the control in plant height, leaf length and leaf width. The effect was the same for leaf area, plant weight and N.P and K uptake. However, all the amended soils were significantly ($p < 0.05$) better in affecting lettuce growth than the control. The application of phosphocompost increased the soil organic matter content as well as increase in soil nutrients such as available P, K, CEC and total N. There were also increase in soil pH, organic carbon, exchangeable bases, percentage base saturation and decrease in exchangeable acidity.

6.2 Conclusion

From the results, the following conclusions were made:

It was observed that, composting Togo Rock phosphate with poultry manure, cattle manure and pig manure effectively influenced the release of phosphorus, with poultry manure showing the best results. The application of phosphocompost increased the soil chemical properties such as organic matter content as well as increases the other soil nutrients such as available P, CEC, TEB and total N. The application of phosphocompost generally influenced all treatment combinations to record significantly ($p < 0.05$) higher plant height, leaf length, leaf width, leaf area, plant weight and nutrient content than the sole soil. However, the best performances were recorded by treatment RP + PM 1:3 throughout the growth period.

6.3 Recommendations

- Due to high cost of soluble P fertilizers in the market, vegetable farmers can adopt phosphocompost to reduce cost.
- Since phosphocompost was effective in increasing both macro and micro nutrients in soil, agricultural policy makers should supply rock phosphate at a subsidized price to motivate vegetable farmers to use phosphocompost for effective growth and yield since rock phosphate and animal manures are easily accessible in their localities.
- Further research is recommended to establish the actual ratio of rock phosphate to manure which will make economic sense.

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APPENDIX A

Average nutrient concentrations of livestock manure (Combs et al., 1999)

	N	P	Ca	Mg
Cattle manure	13.5	9.8	51.8	17.6
Pig manure	27.6	60.2	33.9	7.5
Poultry manure	94.8	90.4	191.9	10.6